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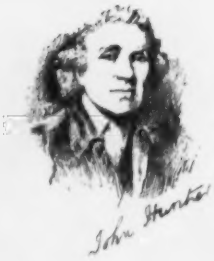

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The Journal of
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EDITORIALS AND ANNOTATIONS

TREATMENT OF TUBERCULOSIS OF THE SPINE

Evaluation of the methods of treatment of skeletal tuberculosis is both necessary and difficult at this time—necessary because we are now approaching the time when the value of antibiotics may be reasonably assessed, and difficult because of the many factors to be taken into account, such as the age of the patient, the site of the disease and even the part of the country.

There seems to be reliable evidence that the primary mortality in bone and joint tuberculosis has been reduced by the use of antibiotics. If this be accepted, then recurrence of disease assumes an even greater importance in the assessment of results than it had in the past. Changes in the accepted methods of treatment should await reliable evidence not only that the mortality rate is less, but that morbidity is reduced through less time in hospital and fewer recurrences.

Direct attack on a focus of tuberculous disease has been an accepted method of approach when it was—or appeared to be—possible to excise completely the diseased organ or tissue. When removal was not possible the indications for early surgery were less clearly defined and less generally accepted. The risks of general dissemination of the disease and of the formation of sinuses were strong deterrents to adventurous surgery. These two possible complications, which were perhaps over-emphasised in the past, may now be less important since the introduction of the antibiotics. Direct attack on spinal disease by the antero-lateral approach was first carried out by Menard and others towards the end of the last century. These procedures were principally concerned with drainage of the diseased site, and the results were such that the operation was abandoned. Ito *et al.* (1934) reported ten patients treated by partial or complete excision of thoracic vertebrae by the costotransversectomy approach, and of lumbar vertebrae by the extraperitoneal approach. All the patients survived the operations, but sufficient time had not elapsed at the time of writing to assess the results. Since then no further report on the condition of these patients has appeared. No reports of other series treated by this method have been discovered since then except that by Felländer quoted below. I understand that the method has been used by Kastert of Stuttgart and that some results have recently been published—though it has not been possible to obtain a copy of this publication.

The results of treatment by conservative measures, including spinal fusion after the disease has been arrested, leave much to be desired, but they have been better than those produced by any other method up to the present. The principal drawback has been the long period of treatment required, with its inevitable mental and physical trauma.

Anything that can be done to decrease the length of treatment and still produce equally good short-term and long-term results is to be welcomed. It is perhaps wise to recall that, owing to the chronic nature of the disease, it is present in the spine for a year or more before diagnosis is possible, and that the safety of the patient—so far as the future is concerned when treatment is completed—depends as much on the general as on the local resistance to the disease. Much of the generally accepted regime of conservative treatment has been based on these two points.

In this number of the Journal Wilkinson mentions some published results of conservative treatment. The two series published by Girdlestone to which he refers were designed to compare the results of conservative treatment alone with those of conservative treatment followed by grafting when the disease was arrested. In the latter group 65 per cent were well and working after five years. Of the 15 per cent not mentioned by Wilkinson 8 per cent had been excluded because it was not possible to trace them, and 7 per cent because their treatment had not been completed five years before the follow-up was undertaken. It was established that none of the 8 per cent had died. The figure of 65 per cent was therefore a conservative estimate, and might have been increased by some of the missing 15 per cent. This review was carried out twenty years ago.

In Wilkinson's series the number of cases in each group is too small to bear statistical analysis, and, although they are grouped together in the summary from the point of view of results, no composite analysis is given of the length of follow-up, length of stay in hospital, further operations, etc. For instance, of the thirty-four adults only four had been followed up for five years. If bony ankylosis is accepted as the criterion of a satisfactory result in established spinal tuberculosis, the proportion of those in which a satisfactory result was obtained was 55·4 per cent.

Felländer (1955) has recently produced a complicated analysis of 100 patients in which surgical attack on the vertebral lesion was carried out. This paper demonstrates very well the difficulty of subjecting all the various factors to analysis. For example, in thirty-nine patients spinal fusion had been carried out before the radical operation, and in twenty-six it was undertaken after the radical operation. These sixty-five patients are compared unfavourably with thirty-six in which no spinal fusion followed the radical procedure. The thirty-nine patients represented a group in which the conservative treatment had failed to arrest the disease. No comparison is made of the twenty-six grafted after the radical operation with the thirty-six in which no graft was carried out. In this group of 100 no less than thirty-six had recurrence of sinuses or abscesses after the radical procedure. In thirty of these patients forty additional operations were carried out in relation to the recurrence of disease. The average length of hospital treatment was 169 ± 12 days. The period of observation was one to four years. Sixty-two patients were fully able to work, and seventy-three could be regarded as clinically healed with respect to the spondylitis. The mortality rate in the group during the period of observation was 9 per cent, three deaths being directly related to the operation. No brief comment on this excellent analysis can do it justice, and those interested in this subject are advised to read it in full.

We are all searching for steps that will shorten the long period of treatment required, if it continues to be based on conservative measures designed to produce good general health, arrest and quiescence of the local lesion and a strong and stable spine at the site of the disease. It may be that the direct attack on the spinal lesion by removal of diseased tissue, and improvement in blood supply to the remaining bone, will provide a step in this direction. But the evidence that this method decreases morbidity and leads to better long-term results is as yet insufficient to justify its general acceptance. J. C. Scott.

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ARTERIAL INJURIES AND ORTHOPAEDIC OPERATIONS

Papers in this issue by A. Webb-Jones and by J. H. S. Scott remind us again of the dangers of unsuspected damage to arteries during operations performed with the aid of a tourniquet. Such injuries are probably much commoner than we think. If an artery no larger than the dorsalis pedis is completely divided during such an operation little ill effect is to be expected. The cut vessel will retract and close. The dressing or the plaster may be more heavily bloodstained than usual, but the amount of blood lost will do no great harm, the blood will escape into the dressing and will not unduly delay healing, and the collateral circulation will come to the rescue.

If, however, the artery is " nicked " and not divided completely an arterial haematoma will form. This will eventually become a false aneurysm. If at the same time the adjacent vein is nicked or transfixed, an arterio-venous fistula or an arterio-venous aneurysm is to be expected. Scott and Webb-Jones each report a false aneurysm, and Webb-Jones two arterio-venous fistulae produced in this manner during operations on the ankle and foot with tourniquets. In these cases, as in two others known to the writer of this note, excision of the aneurysm or fistula could be safely performed, and the ultimate result was not affected.

In other parts of the body these vascular accidents can be much more serious, and there is accumulating a disturbing number of reports of such mishaps in orthopaedic operations. Arterio-venous fistulae from transfixion of the anterior or posterior tibial vessels by Steinmann's nails (Gamm 1942, Elkin and Banner 1946, Elkin 1948), false aneurysms of the lateral genicular artery or even of the popliteal (Elkin and Banner 1946, Elkin 1948, Fairbank and Jamieson 1951) after removal of semilunar cartilages are considerably more serious than such lesions in the stabilised foot. Damage of the brachial artery in blood-letting from the median basilic vein was a classical hazard facing the patients of the " ignorant phlebotomist," but it still occurs (Elkin 1948). Arterio-venous fistula of the common femoral vessels after tenotomy of the hip adductors is happily very rare. In one case seen and treated by the writer it cost the patient her leg. Fistulae between the larger femoral vessels are, however, reported in amputation stumps (Stuart 1929, Mason, Pool and Collier 1936), where they can be caused by transfixing the femoral vessels in order to secure a ligature. Fistulae of big vessels can be very dangerous from their well known effects on the hydrodynamics of the circulation. They can produce congestive heart failure very easily. The larger the leak and the closer it is to the heart, the more the effects resemble those of aortic incompetence.

During the last ten years there have been more than thirty reports of such fistulae between the common iliac artery and its own veins or even the inferior vena cava, from accidental damage to these vessels during the enucleation of lower lumbar intervertebral discs (Linton and White 1945, Holscher 1948, Seeley, Hughes and Jahnke 1954, Harbison 1954). At least seventeen of the patients died from the effects of these injuries, and the survival of many of the others depended upon heroic and difficult reconstructive surgery. Most of these accidents happened because pituitary forceps, used for the removal of pieces of disc from the intervertebral space, slipped through ruptures in the anterior part of the annulus fibrosus. It is noteworthy that the majority occurred in operations by very competent surgeons.

There are several morals. In stabilising the foot, full exposure of the joint surfaces to be resected is safer than blind cutting of wedges. This is especially true in the region of the sustentaculum tali, where one of the tendons under the flexor retinaculum (tibialis posterior or flexor hallucis longus) can be seen and respected as a protector of the neurovascular bundle. During the insertion of Steinmann's nails, tenotomy knives or knives for the removal of lateral cartilages, due regard for the known positions of the vessels would seem an elementary need.

In intervertebral disc surgery performed with the patient prone, it is wise to avoid any pressure on the front of the abdomen. Not only does such pressure embarrass the venous

return from the legs and therefore engorge the peridural veins; it may also force the great vessels—and even the ileum (Harbison *loc. cit.*)—tightly against the vertebral bodies and thus into a position of danger. Also, there seems little to justify over-enthusiasm for the removal of every minute fragment from the cavity of the disc, but the best precaution against vascular accidents in these operations is knowledge of their possibility.

If any of these mishaps should occur, the outcome depends very largely on prompt diagnosis and treatment. No surgeon practising intervertebral disc surgery can afford not to read the papers mentioned, for it is only from the recorded experience of others that the syndromes produced by these catastrophes may be recognised at once and repaired at the right time.

D. Ll. Griffiths.

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THE VASCULAR PATTERN AS AN AID TO THE DIAGNOSIS OF BONE TUMOURS

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The interpretation of the clinical and radiological manifestations of bone tumours may be neither easy nor successful. Biopsy, a procedure not without its hazards, may not always be decisive, for the physical characteristics of bone make microscopy difficult, and sometimes the part of the tumour selected for examination does not represent its true character. Thus

Fig. 1

Fig. 2

Fig. 3

Figure 1—Normal common femoral arteriogram. Figure 2—Humerus showing vascular channels. Note minute nutrient foramen (arrow). Figure 3—Radiograph taken at the end of injection of 20 cubic centimetres of 50 per cent diodone into the medial malleolus in five seconds. Note concentration in deep, communicating, and superficial veins of the leg. Very little medium remains in the marrow veins.

in a recent survey of 517 cases from the Bristol bone tumour register, Walker (1954) found that in fifty-five the diagnosis still remained debatable after careful clinical, radiological, and pathological examination. As weighty decisions have to be made concerning amputation, biopsy, and the best use of surgical and radiation therapy, any attempt to obtain further information seems worth while. A study of the vascular pattern of suspected bone tumours has been found to provide both positive and negative information of value in diagnosis and in planning treatment.

THE NORMAL BLOOD SUPPLY OF BONE

The study of a normal arteriogram of a limb shows that the branches of the main artery follow a slightly curved and undulating course, and that their calibre slowly and

progressively decreases (Fig. 1). None of these vessels is seen to reach the periosteum, nor is the nutrient artery ever visible. Inspection of a long bone from which the periosteum has been removed reveals numerous minute holes along the diaphysis, particularly near the muscular and ligamentous attachments, and some larger holes are found near the epiphyses (Fig. 2). The small foramina transmit tiny periosteal arteries, the larger ones veins. When the periosteum is stripped off the bone at operation, relatively little oozing occurs. These observations might suggest that the blood supply of bone is relatively poor. If, however, a contrast medium is injected directly into the bone it is found that these minute periosteal vessels are capable of dealing with it in a truly remarkable way (Fig. 3). These channels through which the contrast medium leaves the bone are so small that they are invisible radiologically, but so numerous that the deep and superficial veins are flooded with a concentration of opaque material far

FIG. 4

FIG. 5

FIG. 6

Figure 4—Radiograph taken at the end of injection of 20 cubic centimetres of 50 per cent diodone into the tibial tuberosity in five seconds, in a case of acute thrombophlebitis of the deep veins of the leg and pelvis. Note rapid dissemination into the superficial thigh veins. No periosteal channels are visible. Figure 5—Venogram of azygos system, in a case of thrombosis of the inferior vena cava, after injection of the spinous process of the first lumbar vertebra (arrow). Figure 6—Venogram of the leg showing tortuous vessels throughout the bone marrow in man aged fifty-four years who had suffered from varicose ulceration and eczema for thirty years.

greater than that which occurs after it is introduced directly into the venous system (Begg 1954). This rapid dispersion is in no way hampered by thrombosis of the deep veins of the limb (Fig. 4). The capacity of these vessels is well illustrated in the case shown in Figure 5, in which 20 cubic centimetres of 50 per cent diodone were injected into the spinous process of L.1 vertebra in four seconds in a patient suffering from thrombosis of the inferior vena cava. A film taken at the end of the injection shows that the medium has already left the vertebra and has reached the heart by way of the paraspinal venous plexus and the azygos vein.

Although most of the medium appears to pass out through the periosteal channels near the site of injection, some passes along the marrow cavity in tortuous communicating vessels which may extend throughout the bone (Fig. 6). In view of this the safety of biopsy seems to be in question, for a tourniquet cannot control the circulation through the bone marrow.

Bone, therefore, appears to behave like a sponge through which a great volume of blood is rapidly circulating. It is supplied by minute periosteal vessels most numerous in the region of the epiphyses. The nutrient artery plays little part in its nourishment and may be regarded as a vestigeal structure indicating the situation of the foetal diaphysis and the most avascular region of the adult bone.

METHOD OF EXAMINATION

This is in the main by arteriography. Lesions in most parts of the skeleton may be investigated in this way by selecting the appropriate vessel. It is possible to inject by direct puncture any vessel that can be palpated, and some others such as the aorta, the vertebral and the subclavian arteries by virtue of their good bony landmarks. Arteriography can usually

FIG. 7

Normal subclavian arteriogram with tourniquet applied around the upper arm, demonstrating the branches of the subclavian and axillary arteries.

be carried out quickly and easily under local anaesthesia without causing the patient more discomfort than is occasioned by an intravenous pyelogram. Most examinations, therefore, may be carried out as out-patient procedures. Surgical exposure of the vessel should never be necessary.

For lesions of the head and neck the carotid or vertebral arteries are used, for the shoulder girdle or the arms the subclavian artery, and for the forearm the brachial artery. The pelvic bones may be investigated by injecting the abdominal aorta, preferably below the origin of the renal arteries. The thigh is examined by injecting the common femoral artery, either in a proximal or distal direction, or the superficial femoral or profunda femoris artery, according to the region under investigation. The arteries of the leg are usually well demonstrated by injection into the superficial femoral artery, but injection of the dorsalis pedis or posterior tibial arteries may be required to demonstrate the vessels of the foot, especially if obliterative arterial disease is present in the leg.

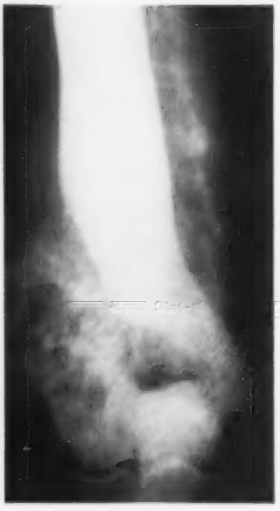

FIG. 8

FIG. 9

FIG. 10

FIG. 11

Figures 8 to 12 relate to the same patient, a man of seventy-four years.

Figure 8—Radiograph of the right elbow showing extensive destructive lesion.

Figures 9 and 10—Brachial arteriogram. Film taken at the end of injection (Fig. 9) shows large arteries feeding the tumour. A film taken two seconds later (Fig. 10) shows the tumour circulation and the drainage by way of large newly formed veins.

Figure 11—Venogram through the lower end of the radius shows the normal arm veins in relation to the tumour.

Figure 12—Section of the lower arm showing the extent of the tumour.

FIG. 12

It has been found helpful, and for the shoulder and pelvic girdles essential, to apply a tourniquet immediately distal to the lesion for the short period during which the injection is made (Fig. 7). For this purpose a pneumatic tourniquet of the Conn type has been found suitable, because it is easily applied and released, is relatively comfortable for the patient, and arrests completely the blood flow through the soft tissues at any level in the arm or leg. By this means the smaller arteries are demonstrated, and the flow of the medium is so retarded that rapid serial films become unnecessary. Thirty-five per cent diodone solution has proved sufficient for all arteries except the aorta, where a 70 per cent solution is required. The timing of the exposures is suited to the particular problem in hand. A simple cassette changer which allows three films to be exposed at intervals of two seconds or more is used.

In suspected vascular tumours of the spine or skull direct injection may sometimes reveal the nature of the lesion.

DISCUSSION AND ILLUSTRATIVE CASE REPORTS

As in corresponding tumours of the brain and kidney, the blood supply of malignant tumours of bone appears to be increased. This declares itself radiologically by visible arteries to the periosteum and by abnormal vessels feeding the tumour. These vessels no longer decrease in calibre but remain the same size over some distance or increase in diameter and become tortuous. In addition, the rapid circulation through the vascular sinuses of the tumour may be demonstrated, and a general increase in the opacity of the lesion may occur as the contrast medium passes through it.

Some of these characteristic features are illustrated in the case of a man aged seventy-four years. Owing to mental confusion the history was unreliable, but, on examination, a large, hot, tender swelling was found above the right elbow. This pulsated slightly and a bruit could be heard over it. Radiography of the elbow supported the clinical diagnosis of osteosarcoma (Fig. 8). No evidence of Paget's disease was discovered. On injection of the brachial artery with 35 per cent diodone the tremendous vascularity of the lesion became obvious (Fig. 9). Greatly enlarged radial recurrent and supratrochlear arteries were the chief feeding vessels. A film taken two seconds later showed the circulation within the tumour and its venous drainage into the basilic and axillary veins by way of large, newly formed channels (Fig. 10). An increase in the density of the tumour demonstrated its spread into the soft tissues medial to the humerus. A venogram, using the lower end of the radius, showed how the normal veins were displaced but not occluded by the tumour (Fig. 11). Here, then, were two separate circulations of almost equal volume—one to the tumour, the other to the arm. These findings made the diagnosis certain. No treatment was undertaken and the post-mortem examination three weeks later revealed an osteosarcoma arising from the lower end of the humerus (Fig. 12).

It is, however, in cases in which the diagnosis is in doubt, and in which the method of treatment is not clear, that a study of the vascular pattern of suspected bone lesions has been particularly useful. The problems arising in six cases that have recently been investigated will serve as examples.

Case 1—Woman aged forty-two years. Nine years previously the patient had sustained a pathological fracture through a cyst in the left radius (Fig. 13) which was successfully treated by a bone graft. Eight years later while combing her hair she first noticed a small, painless swelling on her head. This had possibly increased a little in size since then. A radiograph of the skull (Fig. 14) showed a circumscribed osteolytic lesion in the left parietal bone. Was this another area of dysfibroplasia? In view of her past illness the patient was anxious to know. Direct injection of the lesion under local anaesthesia with 35 per cent diodone showed it to be a cavernous haemangioma (Fig. 15). No immediate treatment therefore was required.

Case 2—Woman aged seventy-eight years. This patient developed a small lump in relation to the left mandible. Part was excised by her dentist and reported as a fibroma of the jaw.

The swelling increased in size, and a further biopsy two months later was described as a fibrosarcoma. On admission to hospital a firm, smooth, rounded mass was found in the left thigh, which was thought clinically to be a subfascial lipoma. Radiography showed a deeply placed circumscribed soft-tissue mass adjacent to the normal femoral shaft. Femoral arteriography revealed a large number of tortuous vessels feeding into the lesion (Fig. 16), and two seconds later a brisk tumour circulation (Fig. 17). In view of this primary or secondary malignant tumour no radical treatment was undertaken. When the patient died two months later the leg tumour had doubled its size.

FIG. 13

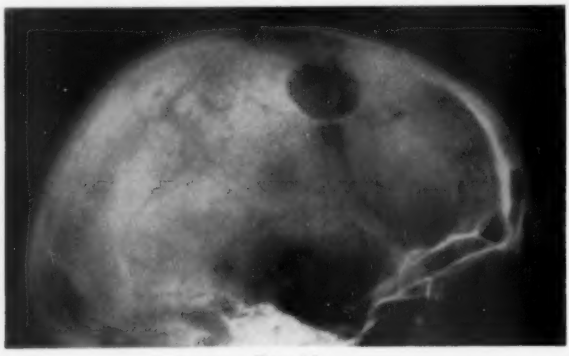

FIG. 14

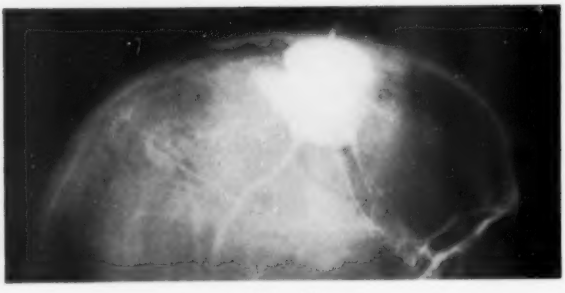

FIG. 15

Case 1. Figure 13—Radiograph showing cyst of the radius with pathological fracture. Figure 14—Radiograph of the skull shows smooth osteolytic defect. Figure 15—Film taken at the end of injection of 20 cubic centimetres of 35 per cent diodone into the lesion. Note branches of the middle meningeal artery feeding the lesion, and diploic and superficial scalp veins draining it.

Case 3—Man aged thirty-nine years. Intermittent pain in the left hip had been experienced by this patient for twelve years. Otherwise his health was good until six weeks previously when a tender, painful swelling of the left hip developed, which did not prevent him from carrying on his occupation as a farmer. Plain radiography showed a smooth erosion of the left greater trochanter, with some calcification in the soft tissues nearby (Fig. 18). No evidence of tuberculous disease was seen in the chest or abdomen. Retrograde femoral arteriography with a tourniquet applied in the mid-thigh showed the terminal branches of the lateral femoral circumflex artery stretched around an avascular mass (Fig. 19). No evidence of tumour circulation was seen. This was thought to confirm the diagnosis of a tuberculous bursitis. At operation the trochanter was found to be flattened and a large tuberculous abscess was drained.

FIG. 16

FIG. 17

Case 2—Femoral arteriogram. Film taken at the end of injection (Fig. 16) shows large number of tortuous vessels feeding into the tumour, and film two seconds later (Fig. 17) shows an increase in the density of the mass as the contrast medium circulates through it.

FIG. 18

FIG. 19

Case 3. Figure 18—Radiograph of the left hip. Smooth erosion of the greater trochanter and calcification in the soft tissues (arrow). Figure 19—Femoral arteriogram with tourniquet applied to the upper thigh shows displacement of the terminal branches of the lateral femoral circumflex artery.

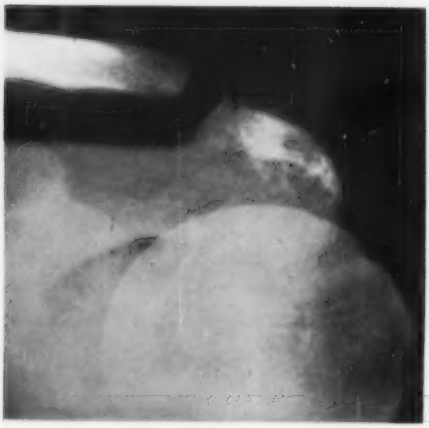

FIG. 20

FIG. 21

Case 4. Figure 20—Film of acromion process shows small osteolytic areas and a rounded soft-tissue swelling. Figure 21—Subclavian arteriogram with tourniquet applied to the upper arm shows slightly enlarged branch of the posterior circumflex humeral artery (arrows) feeding into the lesion.

FIG. 22

FIG. 23

FIG. 24

Case 5. Figure 22—Radiograph of the left knee showing erosion of the upper portion of the fibular head and osteolytic lesions in the shaft. Figure 23—Superficial femoral arteriography with a tourniquet applied to the upper third of the leg shows no abnormality of the vascular pattern. This film taken fifteen seconds after the injection shows how the contrast medium is retarded by the tourniquet with good visualisation of the smaller vessels. Figure 24—Section of surgical specimen shows cystic spaces and fibrosis in the upper three inches of the fibula.

Case 4—Woman aged thirty-three years. Seven years previously excision of a lump above the right elbow revealed a lymphosarcoma. Recurrences in various places always responded rapidly to deep x-ray treatment. The patient was well until two weeks before when she suddenly complained of severe pain over the left acromion process. This was thought to be due to bursitis. Plain radiography showed small areas of rarefaction in the tip of the acromion beneath a small, smooth, soft-tissue swelling (Fig. 20). Were the changes in the bone secondary to the overlying inflammation, or was the soft-tissue swelling secondary to lymphosarcomatous deposits in the acromion? Injection of the subclavian artery with a tourniquet applied to the upper arm showed that one of the terminal branches of the posterior circumflex humeral artery maintained and even increased its calibre slightly as it neared the acromion (Fig. 21). This was taken to indicate that the lesion was a secondary lymphosarcomatous deposit. Symptoms, and the tumour, rapidly disappeared with deep x-ray treatment.

Case 5—Woman aged twenty-five years. This teacher was moving a piano at school when it fell over on to her left leg, grazing her knee and injuring her foot. Clinical examination suggested the possibility of injury to the bones of the foot and possibly to the patella. Radiography of the foot and knee showed no evidence of injury but revealed pathological changes in the upper part of the left fibula (Fig. 22). Here parts of the cortical bone had disappeared and osteolytic areas extended three inches down the fibular shaft. Injection of the superficial femoral artery with a tourniquet applied around the middle of the leg (Fig. 23) showed that the vessels in relation to the head of the fibula were normal, and that there was no increase in vascularity. This was taken to indicate that the lesion was simple, and that it was not a haemangioma. The upper part of the shaft of the fibula was exposed and, because no infiltration of the surrounding tissues was observed, it was excised. Pathological examination showed fibrous dysplasia of bone (Fig. 24).

Case 6—Woman aged twenty years. This patient complained of a slight stiffness of the left knee eleven weeks previously and, six weeks later, occasional stabbing pains over the inner aspect of the left knee. Clinically, apart from a little tenderness over the lower femur, nothing abnormal was found. Radiography showed an area of periosteal reaction over the inner aspect of the lower femoral shaft and a vague area of osteolysis (Fig. 25). Tomography demonstrated the extent of the lesion better, and revealed a small break through the cortex (Fig. 26). Was this an osteosarcoma? Femoral arteriography showed that a branch of the descending genicular artery was considerably increased in size (Fig. 27). Periosteal vessels were visible and a tumour circulation was demonstrated. This was taken to indicate that the lesion was in fact an osteosarcoma. A frozen section biopsy taken after the application of a tourniquet confirmed this, and amputation through the thigh was performed. Figure 28 shows a cross-section of the tumour.

CONCLUSIONS

It will be seen that a study of the vascular pattern of suspected bone tumours has proved helpful in both a positive and negative way. This additional information has permitted a more certain diagnosis, and in some cases appears to provide such sure evidence of osteosarcoma that any hazard of dissemination by biopsy may be avoided. It seems that the following may be taken as positive evidence of malignant tumours: 1) visible periosteal vessels; 2) an increase in the calibre of feeding arteries and draining veins; and 3) a tumour circulation.

SUMMARY

1. Direct injection of contrast material into bone indicates its extreme vascularity, particularly near an epiphysis, and emphasises the extraordinary capacity of the minute periosteal vessels. The nutrient artery of a long bone appears to play little part in its nourishment and may be regarded as a vestigeal structure.

FIG. 25

FIG. 26

Case 6. Figure 25—Radiograph of lower left femur shows periosteal reaction and vague areas of osteolysis in the lower femur. Figure 26—Tomograph shows the extent of the lesion better and demonstrates a small rupture of the cortex (arrow).

FIG. 27

FIG. 28

Case 6. Figure 27—Femoral arteriogram shows an abnormal branch of the descending genicular artery, visible periosteal vessels (arrow), and a tumour circulation. Figure 28—Section of the left thigh shows the extent of the osteosarcoma.

2. The vascular pattern of bone tumours may be investigated by injection of the appropriate artery, and sometimes, if a haemangioma is suspected, by direct injection into the lesion.

3. The examination is easily and quickly carried out by direct arterial puncture under local anaesthesia and injection of 35 per cent diodone. A tourniquet applied distally at the appropriate level is often helpful.

4. A study of the vascular pattern of suspected bone tumours has provided useful information in a positive and negative way, assisting both the diagnosis and the planning of treatment. The pathological diagnosis of some tumours, notably osteosarcomas and haemangiomas, may be made with such assurance that possible dissemination of the tumour by biopsy may be avoided.

It is a pleasure to thank those colleagues who have referred their patients to me for investigation. My thanks are also due to Professor R. McWhirter (Edinburgh) and Professor N. W. Nisbet (Dunedin), without whose encouragement these observations would not have been recorded. Miss D. Marshall greatly assisted with the illustrations and Mrs C. Leaver with the manuscript. Their help is much appreciated.

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THE TREATMENT OF TUBERCULOSIS OF THE SPINE BY EVACUATION OF THE PARAVERTEBRAL ABSCESS AND CURETTAGE OF THE VERTEBRAL BODIES

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The introduction in the early part of the century of open-air hospitals for the treatment of patients with tuberculous joints made possible the good results that were obtained with conservative treatment. The introduction of antibiotics has made possible further progress. In October 1951 the author (Wilkinson 1952) read a paper at a meeting of the British Orthopaedic Association, reporting early results of the treatment of twenty patients by curettage of the tuberculous spinal lesion, an operation which would not have been safe without antibiotic cover. The number of patients so treated who have been discharged from hospital has now risen to sixty-five, and sufficient time has elapsed to make it possible to assess the method. Good though many of the results were that could be obtained by constitutional treatment only, tuberculosis of the spine remained a severe disease, with a high mortality rate even after prolonged treatment. For example, Girdlestone (1940) reported a five-year follow-up of patients treated conservatively of whom 5 per cent had unsatisfactory results and 28 per cent had died: only 53 per cent were known to be well and working. Another series reported by Girdlestone, in which the patients had a posterior spinal fusion in addition to conservative treatment, contained after five years 4 per cent with unsatisfactory results, 16 per cent who had died, and only 65 per cent who were well and working. Dobson (1951) reported a mortality rate of 18·7 per cent during treatment and 23 per cent after a follow-up of three years. Cleveland (1935) reported a 29 per cent mortality after a three-year follow-up, and Harris and Coulthard (1942) 29 per cent after a follow-up varying from one to ten years. The need for improved methods of treatment is therefore clear.

The sixty-five patients in this series have been divided into various groups for discussion. The fourteen children operated upon are placed in a separate category because the disease is more rapidly destructive of vertebrae in children and the precise time at which the operation is performed is of greater importance than in adults, and has greater significance than the situation of the spinal lesion. It should be mentioned, however, that nine of the children had disease of the thoracic spine and five of the lumbar.

The adults are divided into two groups, one consisting of thirty-four patients who had disease in the mid-thoracic or lower thoracic region and seventeen who had disease in the lumbar region. Each of these groups is divided into two sub-groups, one of patients operated upon in the relatively early stages of the disease during their first admission, and the other of patients operated upon late in the disease on account of readmission for reactivation or for chronic sluggish disease.

The sixty-five operations consisted of evacuation of paravertebral pus and curettage of the tuberculous disease in the vertebral body, a procedure which, for the sake of brevity, will be referred to as "central curettage." Patients with paraplegia or patients treated by sequestrectomy for chronic secondary sepsis of the vertebrae have not been included in this series.

OPERATIONS ON CHILDREN

The results of central curettage in this group of fourteen patients are shown in Table I.

The children in the Table are divided into four sub-groups. The first to be considered are three children with early actively progressing tuberculosis of the lower thoracic vertebrae,

accompanied by a paravertebral abscess. This type of disease, treated by constitutional measures alone, used frequently to cause much vertebral destruction and gross deformity. Two of these children were operated upon a month after admission, and a third, who had a pleural effusion, four months after admission. All were discharged with bony anyklosis after a period of treatment averaging thirteen months (Figs. 1 to 4). It may be noted here that whereas a paravertebral abscess accompanying a thoracic spinal lesion is clearly visible in

TABLE I

RESULTS OF TREATMENT BY CENTRAL CURETTAGE IN FOURTEEN CHILDREN SUFFERING FROM TUBERCULOSIS OF THE SPINE

	Number of patients	Bony ankylosis	Sound fibrous ankylosis	Unstable ankylosis
Early operation for active disease .	3	3	0	0
Later operation for active disease .	5	4	0	1
Late operation for reactivated lesions	3	2	0	1
Late operation for increasing deformity	3	1	0	2
	14	10	0	4

radiographs, that accompanying a lumbar lesion is not clearly visible. If, in a child with lumbar vertebral disease, a psoas abscess forms, the prognosis is good. If, however, progressive caries is observed in a child who has no psoas abscess, the presence of paravertebral pus should be suspected and early exploration by means of lumbar transversectomy considered.

The next sub-group consists of five children who were operated upon when the disease was still active and progressive but after a longer interval, which averaged eleven months between admission and operation. These children were among the earliest in the series and the reason for the delay in operating was uncertainty about miliary tuberculosis. Four obtained bony anyklosis, but this developed gradually after discharge from the hospital, and their duration of hospital treatment averaged twenty months, as opposed to thirteen months for the group operated on soon after admission. One of the children required readmission for a full course of antibiotics and posterior fusion and later developed bony ankylosis. The child who developed unstable ankylosis relapsed later, but recovered after further treatment though with gross deformity.

The next sub-group consists of three children with tuberculosis of the lumbar spine operated upon late in the disease on account of reactivation. Two subsequently developed bony ankylosis. The last group is of three children operated upon late in the disease with a view to preventing deformity. In one instance bony anyklosis developed (Figs. 5 to 7); in another child there has been reactivation of disease necessitating further treatment.

CENTRAL CURETTAGE IN ADULTS WITH TUBERCULOSIS OF THORACIC VERTEBRAE

Twenty-seven patients with tuberculosis of the mid-thoracic or lower thoracic vertebrae were operated upon during the relatively early stages of the disease, and seven were operated upon late on account of reactivation. The results of treatment in the first group are shown in Table II.

Since vertebral destruction takes place more slowly in adults than in children there is not the same need for early operation, provided that serial radiographs do not show progressive vertebral destruction. The delay allows the patient's general condition to improve, permits resolution of oedema in the soft tissues surrounding the lesion, and favours wound healing. On the other hand the removal of paravertebral pus has a beneficial effect on the recuperative

FIG. 1

FIG. 2

Case 1—Radiographs of an early tuberculous lesion of T.10–12, with paravertebral abscess, in a child of two and a half years. Curettage was carried out six weeks after these radiographs were taken.

FIG. 3

FIG. 4

Case 1. Figure 3—Condition at time of discharge from hospital fourteen months later. No apparatus worn.
Figure 4—Condition one year after discharge.

FIG. 5

FIG. 6

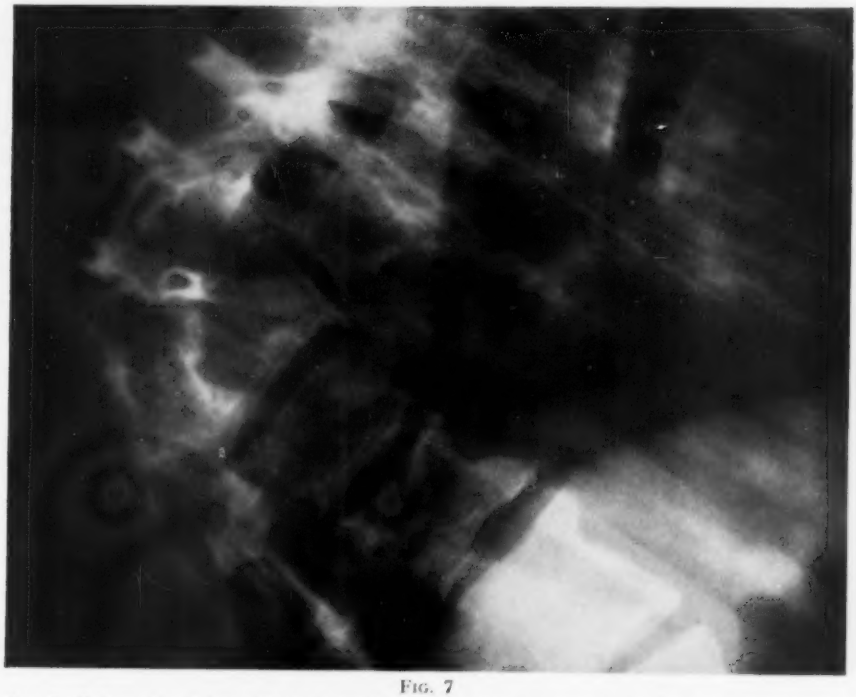

FIG. 7

Case 2—Tuberculous lesion of T.7–9 in a girl of twelve years. Figure 5—During initial conservative treatment. A short posterior graft was inserted. Figure 6—Condition five years later, showing granuloma and increased deformity. Curettage of the lesion and insertion of bone chips were performed soon after this film was taken. Figure 7—Radiograph three years later, showing bony ankylosis. No significant increase in deformity.

power of the bone (Swett *et al.* 1940). Also, experience has shown that antibiotic treatment, unsupported by operation, has very little effect on established tuberculous lesions of the spine (Stevenson 1954, Wilkinson 1954). There is, therefore, good reason to operate early to remove ischaemic tissue and to provide access of the antibiotic. The author usually waits for three or four months before operating on adults; for children such a delay is too long.

TABLE II

RESULTS OF CENTRAL CURETTAGE IN TWENTY-SEVEN PATIENTS WITH TUBERCULOSIS OF THE MID-THORACIC OR LOWER THORACIC VERTEBRAE, OPERATED UPON DURING THE RELATIVELY EARLY STAGES OF THE DISEASE

Duration of follow-up	Number of patients	Bony ankylosis	Reformed vertebral bodies	Firm fibrous ankylosis	Unstable ankylosis
5 years . .	2	2	0	0	0
4 years . .	2	2	0	0	0
3 years . .	3	3	0	0	0
2 years . .	7	4	0	1	2
1 year . .	10	7	0	2	1
Under 1 year	3	0	2	1	0
	27	18	2	4	3

It will be noticed from Table II that all of the seven patients who were followed up for three years or more have solid bony ankylosis. Some of those classified as having firm fibrous ankylosis will undoubtedly develop bone fusion later. The average duration of treatment was nine and a half months. One patient, whose operation was not technically satisfactory,

TABLE III

RESULTS OF TREATMENT BY CENTRAL CURETTAGE IN SEVEN PATIENTS WITH TUBERCULOSIS OF THE MID-THORACIC OR LOWER THORACIC VERTEBRAE, OPERATED UPON LATE IN THE DISEASE ON ACCOUNT OF REACTIVATION

Length of follow-up	Number of patients	Bony ankylosis	Firm fibrous ankylosis	Unstable ankylosis
6 years .	2	2	0	0
4 years .	2	1	0	1
3 years .	2	0	1	1
1 year .	1	0	0	1
	7	3	1	3

relapsed later: after further operation she has now a bony ankylosis. Figures 8 to 10 show bony ankylosis occurring after operation in a successful case. The results given in the Table show that twenty-four of the twenty-seven patients, or 88·8 per cent, had a secure stable spine on follow-up: this figure may be compared to another, previously published by the author (Wilkinson 1949) as the result of investigating a series of patients treated by conservative

FIG. 8

FIG. 9

FIG. 10

Case 3—Tuberculous lesion of T.10–11 vertebrae in a young woman. Paravertebral abscess present. Figures 8 and 9—Antero-posterior and lateral radiographs taken three months after admission and three months before operation. Figure 10—Radiograph eleven months later, showing bony ankylosis.

FIG. 11

FIG. 12

Case 4—Lesion at L.1–2 vertebrae in a man readmitted on account of pain. He had previously received constitutional treatment, without antibiotics, for a year; nine months later he had been readmitted for further constitutional treatment lasting nine months, during which he also received streptomycin for 100 days. Figure 11 shows the condition when he was again readmitted eight months later. At operation pus was found in the posterior part of the lesion. After curettage, cancellous bone chips were inserted. Figure 12 shows the condition twenty months after operation.

measures only, of whom 49·3 per cent had a stable spine after a follow-up averaging four and three-quarters years. The average duration of follow-up of patients shown in Table II was just under two years.

In addition to the patients operated upon relatively early in the disease, seven were operated upon late in the disease for reactivation of a lesion which had previously been treated by constitutional measures. The alternative to operation for these patients was to submit them to another long course of constitutional treatment. Table III shows that four of the seven patients developed a stable spine after operation. But two of these, who had been operated on when only a minimal course of streptomycin was available, required further treatment, one for a fresh lesion in another part of the spine which also healed after curettage, the other for slight reactivation which responded to a further short period of rest in plaster with a full course of antibiotics. Two of the patients classed as having an unstable spine are at home doing their household duties comfortably. Only one of these patients is at present incapacitated. Their average duration of treatment on readmission was six and a half months.

CENTRAL CURETTAGE FOR ADULTS WITH TUBERCULOSIS OF THE LUMBAR SPINE

Since the prognosis of tuberculosis of the lumbar spine is better than that for thoracic spinal disease, central curettage has seldom been used except for patients whose disease

TABLE IV

RESULTS OF TREATMENT BY CURETTAGE IN FOUR PATIENTS WITH TUBERCULOSIS OF THE LUMBAR SPINE IN THE EARLY STAGES OF THE DISEASE

Duration of follow-up	Number of patients	Bony ankylosis	Reformed vertebrae	Firm fibrous ankylosis	Unstable ankylosis
2 years .	1	0	0	1	0
1 year .	3	0	2	1	0
	4	0	2	2	0

TABLE V

RESULTS OF CENTRAL CURETTAGE OF THE LUMBAR VERTEBRAL BODIES IN THIRTEEN PATIENTS READMITTED ON ACCOUNT OF REACTIVATION OF DISEASE OR CHRONIC SLUGGISH DISEASE

Duration of follow-up	Number of patients	Bony ankylosis	Firm fibrous ankylosis	Unstable ankylosis
4 years . .	3	1	0	2
3 years . .	1	0	0	1
2 years . .	4	2	2	0
1 year . .	3	2	1	0
Under 1 year	2	0	1	1
	13	5	4	4

relapsed or remained chronic after constitutional treatment. Because it has succeeded in these unfavourable cases there is probably greater scope for its use earlier, particularly for lesions in the posterior parts of the lumbar vertebrae, which are more easily accessible than

lesions in the anterior parts. Four patients who were operated upon during the earlier stages of the disease are recorded in Table IV. One of them who is shown as having healed with a reformed vertebra later suffered a relapse from fresh disease in neighbouring vertebrae.

The average duration of treatment was eleven and a quarter months. Thirteen patients were operated on for relapse of lumbar disease after previous constitutional treatment. The symptoms or signs presented by these patients were either pain, or the formation of a psoas abscess, or progressive vertebral destruction seen in the radiographs, or a combination of these. In some patients the pain had a segmental distribution and was immediately relieved by operation. In one patient a lumbar nerve root was found stretched over a spur of bone. Relapse with psoas abscess was treated by curettage of the vertebral lesion with, at the same operation, evacuation of the pus in the psoas abscess through a small anterior incision which was resutured. There have been two relapses, one of a patient operated on very early in the series and another who has recovered after a second operation. The average duration of treatment on readmission of patients in this group was six and a half months (Figs. 11 and 12).

OPERATIVE CONSIDERATIONS

There has been no operative mortality and no anxiety has been experienced on account of possible miliary dissemination. Sinus formation in the line of incision has not infrequently followed, but except in two patients the sinuses have been of short duration. Occasionally a cold abscess has appeared under an operation scar months after treatment when the spine

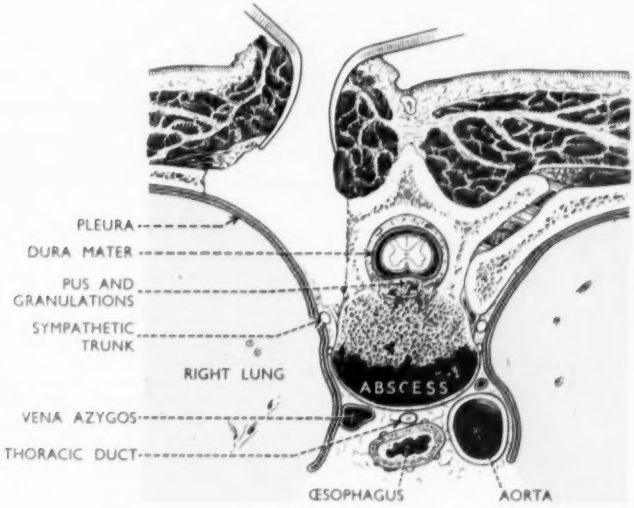

FIG. 13

Illustration showing the position and relations of a tuberculous spinal abscess (Rocyn Jones).

has been firmly healed. This is residual pus which was not drained at operation owing to the extensive nature of the abscess.

A two-rib costo-transversectomy has been performed for most patients but a one-rib costo-transversectomy is sufficient for young children. The technique of Menard, to which Capener (1954) has recently redirected attention, has been used. Figure 13, which was devised by Mr Rocyn Jones (1953) and which is reproduced here with his permission, gives a picture

of the condition most often found. It will be seen that clean removal of the rib heads is essential for proper access to the vertebral bodies, and that even when the rib heads have been removed the abscess may not be entered. It is then necessary to shave away the postero-lateral part of the vertebral body until granulomatous material is encountered. Even when the abscess is entered, it may still be necessary to open the vertebral bodies to curette a central granuloma. Sometimes a cavity may be left into which it is possible to pack cancellous bone chips removed from the posterior part of the wing of the ilium. Even in spite of considerable care the pleura may be punctured. The complication of tension pneumothorax may then arise, with consequent dyspnoea and cyanosis. This may rapidly be relieved by inserting a needle into the pleura to reduce the pressure. A pleural effusion is a frequent complication whether the pleura is punctured or not, but seldom requires anything but palliative treatment.

RELAPSES

Ten patients in this series required readmission for further treatment after operation. Six of these patients were among the earliest operated on, when the supply of streptomycin was scanty and when the operation was also sometimes inadequate, because it was not then realised that to find the granuloma the vertebral body might have to be opened (Fig. 14). After further treatment five of these ten patients have recovered with solid ankylosis; one is undergoing treatment for renal tuberculosis, one child is at home and well but has severe deformity, and four patients are still receiving treatment in hospital. In addition there is one other patient, not included in the series because only discharged patients have been included, who is receiving treatment for a secondarily infected sinus after operation sixteen months ago.

FIG. 14

FIG. 14

Tomograph of a lesion of T.11 with a paravertebral abscess. The patient had been treated conservatively for tuberculosis of L.1–2 and was readmitted for the fresh lesion of T.11. On removal of the eleventh rib head, pus was encountered and the postero-lateral aspect of the eleventh vertebral body appeared healthy. On opening the vertebral body, however, a second large granuloma was found within.

SUMMARY

1. Sixty-five patients—fourteen children and fifty-one adults—with tuberculosis of the spine without paraplegia have been treated by evacuation of the paravertebral pus and curettage of the tuberculous focus.

2. Patients were selected for operation mainly because the prognosis without operation seemed doubtful or poor.

3. Sixty of the sixty-five patients are at home and well, most of them engaged in their normal activities. Thirty-six have bony ankylosis of the affected spinal segments, four have re-formed

vertebrae, and eleven have firm fibrous ankylosis. Fourteen still have an unstable spine though some of these are much improved. Thus fifty-one out of sixty-five (or 78 per cent) have a stable and comfortable spine.

4. The duration of treatment of these patients has been considerably less than that formerly necessary. There has been no death among patients treated by this operation. These results show a considerable improvement over those hitherto reported.

I wish to acknowledge the encouragement and help received from the late Mr Paul Swett of Harford, Connecticut, United States of America, Mr S. L. Higgs, and Dr Jack Dixon, whose skill in anaesthesia contributed so much to the safety of the patients. I wish also to thank Mr A. Rocyn Jones for permission to use his illustration.

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SYNOVECTOMY OF THE KNEE IN RHEUMATOID ARTHRITIS

An Essay in Surgical Salvage

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Synovectomy was recorded in 1877 by Volkmann, who operated on a tuberculous knee, but the operation was not attended by any success until in 1899 Mignon carried it out for chronic arthritis (Bernstein 1933). The practicability of the operation was established by Swett (1923, 1939), who first performed it in 1915, unaware that he was not the first to do so. He laid down the principles governing the selection of knees for operation and, referring to " chronic infectious arthritis," stressed the importance of restricting synovectomy to knees in which the changes were largely or exclusively synovial. An opinion commonly expressed by American writers (Bernstein 1933, Ghormley and Cameron 1941, Pardee 1948) is that whereas synovectomy gives good results in persistent or recurrent hydrarthrosis, villonodular synovitis, synovioma and some cases of osteoarthritis, it is less successful in cases of rheumatoid arthritis. Boon-Itt (1930) and Inge (1938) reported improvement in nearly two-thirds of ninety-three knees affected by rheumatoid arthritis or " chronic proliferative synovitis," but an attempt to assess critically the possible value and limitations of synovectomy in rheumatoid arthritis does not appear to have been made except by Swett (1923, 1939).

The purpose of the operation is to try to preserve what useful function the joint still possesses and to relieve pain and swelling. Although the synovial membrane is but one of the tissues affected in rheumatoid arthritis, the fact that its proliferation is associated with progressive damage to articulating surfaces and ligaments makes it seem reasonable to remove this destructive tissue at an early stage. Sometimes it happens that synovectomy—or any other operation—is followed by remission of the rheumatoid process as a whole. Whether such remissions are due to the effect of any stress (including operation) upon the endocrine system or to modification of an allergic process (Novotny 1948) is debatable.

SELECTION OF CASES

Synovectomy was not considered in any case unless treatment by rest and by the accepted medical and physical methods had failed to afford relief. With this proviso, the following were accepted as indications for the operation: 1) pain; and 2) persistent synovial swelling. Operation was not advised unless there was at least 45 degrees of movement (a flexion contracture of up to 30 or 40 degrees does not necessarily rule out synovectomy, for the deformity may yield to preliminary manipulation or to capsulotomy and similar releasing procedures (Pfeiffer and Bach 1940; Preston 1953). Radiographically there should be a good joint space and little or no lipping or subchondral sclerosis. Finally, the patient should be in satisfactory general health and ready and able to co-operate effectively in the post-operative treatment. Anaemia can be corrected fairly quickly by the intravenous injection of iron compounds (Jeffrey 1953), or rapidly by infusing blood. The existence of an acute phase of rheumatoid arthritis must stay the surgeon's hand, although now that A.C.T.H. is available the danger of exacerbation of the disease after operation has been much reduced.

MATERIAL

This paper deals with thirty-four knees of twenty men and seven women who have been subjected to synovectomy since 1946 for suspected rheumatoid arthritis. Nineteen knees have been observed for more than two years after operation. Histological reports were

available in every case except two, and a definite diagnosis of rheumatoid arthritis was made in twenty-eight. In one patient with a clinical diagnosis of rheumatoid arthritis the histologist could find no evidence of the disease and thought the condition might be traumatic. In three instances the appearances were suggestive but not typical of rheumatoid arthritis. The histologist's opinion was based on material selected by him from all or most of the synovial tissue removed at operation, and in many cases also on a small piece of muscle from the site of operation. The importance of histological examination has been mentioned by Heyman (1928) and by Allison and Coonse (1929), who found unsuspected tuberculosis in some of their cases. We have been similarly disconcerted by two of our patients (not included in this series) who had had what was regarded as rheumatoid arthritis for several years but were later proved to have tuberculous arthritis (Kersley 1954). Fortunately, in these days of anti-tuberculous drugs, synovectomy also has a place in the treatment of tuberculosis (Wilkinson 1954).

In all but four cases the erythrocyte sedimentation rate exceeded 15 millimetres in the first hour at the time of operation. Among the four exceptions was the case in which the histological appearance was not like that of rheumatoid arthritis. In five patients the knees were the only joints affected at the time of operation, one of them being the case already mentioned with unproven diagnosis.

THE OPERATION

A parapatellar incision, usually medial, was used in all cases. It gives good access to both sides of the knee. Provided the extensor muscles are split for a hand's-breadth above the patella, this can be turned conveniently aside without effort; incisions that split the patella or cut across its tendon have nothing in their favour. From three knees no more than the suprapatellar pouch was removed, but from all the others as much synovial tissue as could be reached was taken away. Most of the intrapatellar pad of fat was also removed.

An effusion was rarely absent, though its quantity varied much and it sometimes contained solid or semi-solid matter ranging from melon-seed bodies to large masses of greenish-yellow clot-like material. Occasionally the synovial membrane was only slightly thickened, with a smooth, pale pinkish-yellow inner surface, but more often it showed some degree of gelatinous thickening with congestion and polypoid hypertrophy. In extreme cases the membrane resembled purplish seaweed and filled the joint cavity in its profusion. Erosion of articular cartilage by pannus was seldom marked in the knees selected for operation, but, since most of the patients were over thirty, some degeneration of the apposed femoral and patellar surfaces was common and occasionally marked. Softened, velvety cartilage was shaved off and if bare bony surfaces were apposed a sheet of nylon was stitched over the back of the patella to prevent adhesion. This was done on six occasions and appeared to have no disadvantages. We have not used nylon to separate the quadriceps from the femur (McKeever 1943). In one case the back of the patella was sawn off to leave a flat surface: though the patient had smooth, painless movement from 175 degrees to 90 degrees a year later, it remains to be seen what effect the consequent incongruity of the patellar and femoral surfaces will have. If the patellar cartilage is grossly degenerate removal of the patella seems preferable to merely sawing off its articular surface. In this series the policy was to retain the patella whenever possible, and it was removed only twice—once at the time of synovectomy and once six months later, because it had stuck to the femur. Six and a half years after the primary removal the range of movement was 175 degrees to 105 degrees; the delayed removal was followed by a range of 180 degrees to 125 degrees. Provided the patella is shelled out and the extensor mechanism repaired from side to side and not from above down, there seems to be no reason to advise against primary removal of the patella or to modify the post-operative programme for the sake of the healing tendon.

The semilunar cartilages had disappeared from two knees and were damaged enough to be removed from twelve more. Softening and narrowing with ragged concave margins was

the usual finding. Though in most cases the cruciate ligaments were invested by thickened, congested synovium, they were only once recorded as being significantly slack.

At the conclusion of the operation the limb was immobilised on a long plaster back splint.

Post-operative treatment—Three weeks after operation the knee was bent to about a right angle under anaesthesia and returned to a straight back splint. Pain and swelling after manipulation usually subsided in a few days. Quadriceps exercises were begun before operation and continued for a long time afterwards. Apart from the manipulation, occasionally repeated, the patient's own efforts aided by slings, exercises in water, and the physiotherapists' encouragement were relied upon to achieve the final range of movement. When the reaction to manipulation had settled down, the patients were encouraged to walk with a short back splint. This was discarded when the effusion had disappeared and the quadriceps was reliable.

During the period of this survey A.C.T.H., cortisone and hydrocortisone were used in only four instances. The best use of these substances has yet to be finally decided (Medical Research Council 1954), but A.C.T.H. and cortisone are of value in cutting short an exacerbation of the rheumatoid disease, and hydrocortisone injected into the joint has a dramatic though temporary effect in preventing or mitigating flares (Kersley and Desmarais 1952, Hollander 1953).

COMPLICATIONS

Stiffness followed two of the thirty-four operations: one knee was so painful as to require arthrodesis five months after synovectomy; the other was in a state of painless, stable fibrous ankylosis and further treatment was not recommended. In three of the knees operated on early in the series there was enough bleeding to call for reopening of the incision and evacuation of clot. There was no case of infection or shock, though each has been reported as bringing about a fatal issue (Allison and Coonse 1929, Ghormley and Cameron 1941). One patient required excision of the patella, which had become stuck to the femur. One patient wore a caliper for some months, but five years after operation spends much of his working day on his feet, and complains of no more than occasional stiffness and aching.

RESULTS IN TERMS OF MOVEMENT

The range of movement regained in each case is shown in Figure 1. It will be seen that of the twenty-five knees with a range of movement of at least 90 degrees before operation, seventeen retained a comparable range after operation. Only two knees suffered significant loss of movement. Though the ranges tended to be lower four or more years after operation than within two years they remained at least satisfactory, allowing patients to sit and to negotiate stairs without awkwardness.

DISCUSSION

Selection of cases—One of the decisive factors in accepting knees for synovectomy has been the retention of a good or normal joint space, as this has been assumed to indicate that the articular surfaces are good enough to allow useful function if they can be spared, temporarily at least, the ravages of erosion by pannus. It is important to try to assess the validity of this criterion for selecting knees for synovectomy. Three questions must be answered. 1) Is the radiographic appearance a reliable guide to the state of the articular surfaces as seen at operation? 2) Does the functional result depend upon the state of the articular surfaces? 3) Does any other factor influence the outcome?

Comparison of radiographic and operative findings—Eleven knees showed osteoporosis only: five were found to have good or normal articular cartilage, four had slight to moderate erosion and two showed marked degenerative changes. Twenty-one knees showed appreciable

narrowing of the radiographic joint space with or without osteophytes and subchondral sclerosis, but the findings at operation were recorded in only sixteen of these: two knees had good or normal cartilage, eight had slight to moderate, and six gross degenerative changes. Two knees were radiologically normal and at operation both were found to be in good condition. Thus in at least two-thirds of the cases the radiographic appearances gave a reliable indication of the condition of the articular surfaces.

TABLE I

RESULTS IN FIFTEEN KNEES STUDIED FOR LESS THAN TWO YEARS AFTER SYNOVECTOMY, RELATED TO THE STATE OF THE ARTICULAR CARTILAGE AT TIME OF OPERATION

Articular degeneration	Number of knees	Clinical state			Range of movement		
		Much improved	Improved	Not improved	Improved	Not improved	Worse
Little	6	3	3	0	1	5*	0
Moderate	3	1	0	2	1	1†	1
Much	6	1	2	3	2	0	4
Totals	15	5	5	5	4	6	5

* Range good before synovectomy in three cases. † Range good before synovectomy.

Relationship between articular degeneration and function after synovectomy—Since some patients have a warm, swollen, painful joint, which has a good, though hesitant, range of movement, whereas others have a stiff joint but with little or no pain, swelling or warmth, it seems reasonable to separate the range of movement of the knee from its "clinical state" in any attempt to assess this relationship. The "clinical state" is admittedly a rather vague concept

TABLE II

RESULTS IN SEVENTEEN KNEES STUDIED FOR MORE THAN TWO YEARS AFTER SYNOVECTOMY, RELATED TO THE STATE OF THE ARTICULAR CARTILAGE AT TIME OF OPERATION

Articular degeneration	Number of knees	Clinical state			Range of movement		
		Much improved	Improved	Not improved	Improved	Not improved	Worse
Little	5	1	2	2	0	3	2
Moderate	9	4	3	2	3	6*	0
Much	3	1	1	1	0	2†	1
Totals	17	6	6	5	3	11	3

* Range good before synovectomy in two cases. † Range good before synovectomy in one case.

but it does represent an important expression of the reaction of the knee to the rheumatoid process.

Tables I and II show the result of correlating the stage of the articular surfaces with the clinical state and the range of movement in knees studied respectively for less than two years and for more than two years after operation. The numbers are small, but in the first two years the findings seem to support the belief that the improvement is related to the state

of the joint surfaces. After two years this relationship is not evident, and a search is required for other factors capable of influencing the result.

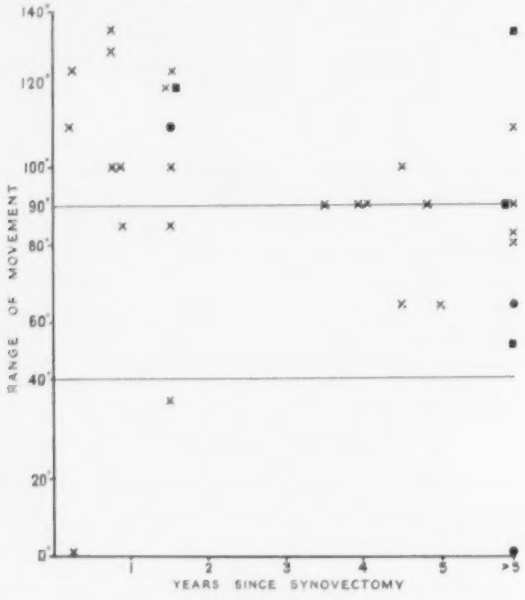

FIG. 1

Relationship between range of movements and interval since operation. X = range at least 90 degrees before operation. ● = range 45–90 degrees before operation. ■ = range before operation not recorded.

Effect of other factors—Experiments with rabbits (Key 1925) have shown that the synovial membrane can regenerate almost perfectly within about sixty days of synovectomy.

No comparably detailed study appears to have been undertaken in man, but synovial regeneration certainly occurs. Efskind (1941) has reported subsynovial fibrosis and a relative lack of blood vessels in regenerated human synovium, and Hosford (1937) reported a normal arthrogram six years after synovectomy. Swett (1923) operated a second time, and successfully, on a knee which relapsed early after the first synovectomy, and Inge (1938) reported regenerated and diseased synovium at a second arthrotomy; so it is clear that reformed synovial tissue is not immune to the rheumatoid process.

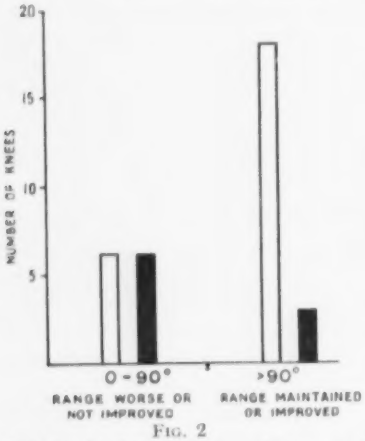

FIG. 2

Relationship between course of disease and range of movement after operation. White columns = course favourable. Black columns = course unfavourable.

From the detailed histories of the patients it has been possible to separate two groups. In one the rheumatoid process had followed a definitely unfavourable course with repeated flares and had involved more and more joints. The other group contained patients whose disease died down at an early stage or else smouldered quietly with little progression. Figure 2 shows the relationship between the range of movement after operation and the course of the disease. It will be seen that of the twenty-one

FIG. 3

FIG. 4

FIG. 5

FIG. 6

Serial radiographs, over five years, of a knee treated by synovectomy. Figure 3—Initial radiograph. Figure 4—Two years later. Figure 5—After three years. Figure 6—After five years. The rheumatoid process was inactive. Despite the progressive development of osteoarthritis a wide range of movement was preserved and function was good.

knees that retained or attained a range of movement of at least 90 degrees after operation, eighteen belonged to patients in the "favourable" group. The twelve knees in which the final range was less than 90 degrees were equally distributed between the "favourable" and "unfavourable" groups. Looked at from another point of view, an unfavourable course was associated with twice as many poor (six) as good (three) ranges whereas in the favourable group, good ranges (eighteen) outnumbered poor (six) by three to one. It therefore seems clear that the activity and progression of the rheumatoid process is an important—perhaps the most important—factor in determining the final range of movement after synovectomy. Support for this belief is provided by the knee illustrated in Figures 3 to 6. In spite of the progressive development of osteoarthritis over a period of five years the range of movement decreased only from 180–85 degrees to 180–100 degrees. During this time the rheumatoid process was quiescent, as indicated by the facts that the knee was cool and there was little effusion and no synovial thickening. Five and a half years after operation function remained good in that the patient was able to do an ambulant job with no more than occasional aching and stiffness after exertion or in bad weather.

SUMMARY AND CONCLUSIONS

1. Synovectomy was carried out in thirty-four knees, of which thirty-one were certainly or probably afflicted by rheumatoid arthritis.

2. Synovectomy was considered only when adequate medical and physical treatment had failed to afford relief. Its purpose is to preserve useful function, and one of the principal factors influencing the decision to operate was the retention of a normal or good radiographic joint space in a persistently painful, warm and swollen knee.

3. Radiographic appearances constituted a useful but not infallible guide to the true state of the articular surfaces.

4. The method of operation, findings and subsequent care are described.

5. Up to two years after operation it appeared that improvement might be related to the state of the articular surfaces, but after two years this relationship was not evident and an attempt to explain this difference has been made.

6. It seems clear that the longer-term results are determined mainly by the course taken by the rheumatoid process. An unfavourable course was associated with considerably less satisfactory results than was a favourable course.

7. It is concluded that in rheumatoid arthritis which has resisted rest and medical treatment synovectomy of the knee is most likely to be successful when the radiographic joint space is good or normal, and when the rheumatoid process follows a favourable course. To undertake the operation at an early stage in the disease is to leave in doubt the outcome, as this is dependent upon the as yet undeclared general course of the disease. Even so, early synovectomy is worth considering when nothing else has given relief. The fact that arthrodesis has only once been necessary after synovectomy appears to justify the policy of salvage described.

It is with pleasure and gratitude that I acknowledge the assistance, criticism and permission to record their patients that Dr G. D. Kersley, Mr John Bastow and Mr A. E. Burton have provided.

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THE NATURAL HISTORY AND PROGNOSIS OF INFANTILE IDIOPATHIC SCOLIOSIS

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In recent years attempts to increase our knowledge of scoliosis, with special reference to the prognosis, have been principally centred on the interpretation and analysis of curve patterns (Ponseti and Friedman 1950, James 1951, 1954). But the normal variations between curves of similar pattern are sufficient to suggest that other aspects of the natural history are equally, if not more, important in assessing the prognosis, which is the principal concern of this paper.

One teaching in scoliosis is that the younger the curve starts the worse it will be when the patient is fully grown. This is in some respects fallacious but it is sufficient justification for focusing attention on infantile scoliosis.

Harrenstein (1936) coined the term " infantile " scoliosis and reported thirty-three cases. He emphasised the importance of early treatment and also observed that in one untreated case spontaneous recovery took place after four years.

In 1951 James described as a clinical entity infantile idiopathic scoliosis. He defined it as " a dorsal scoliosis, present before the age of three, more frequent in boys than girls, with the apex to the left, and progressing to a severe deformity." Although our use of the term as the title of this paper indicates our acceptance of this type of scoliosis as a clinical entity, we differ on some minor aspects of natural history, and for the purpose of this analysis we have accepted as " infantile " curves present at the age of two. The acceptance of this age of onset minimises the accidental inclusion of acquired conditions of known etiology. Progressive infantile idiopathic scoliosis is an appropriate name for this type to differentiate it from the less frequent type in which spontaneous recovery takes place, for which we suggest the name resolving infantile idiopathic scoliosis.

PROGRESSIVE INFANTILE IDIOPATHIC SCOLIOSIS

Material—From 1,200 patients with scoliosis seen at the Wingfield-Morris Orthopaedic Hospital between 1922 and 1952, 218 patients with progressive idiopathic scoliosis were selected for analysis, the selection being based on suitable records and an adequate period of observation. From the analysis we have identified twenty-eight with progressive infantile idiopathic scoliosis. Radiographs taken before the age of two are available in most, and in the remainder there is reliable evidence that the curve was present at that age.

It is of interest to note the lack of reference to this type of scoliosis in American literature. We reproduce in Table I an analysis of 404 cases of scoliosis, of unspecified etiology, reported in 1941 by the Research Committee of the American Orthopaedic Association; our own figures are included in the Table for comparison.

A striking difference is evident. Whereas progressive infantile idiopathic scoliosis (0–2) is represented by twenty-eight cases (12·8 per cent) in our series, only one case was reported in the American series. This group was thus fifty times more common in our analysis. That this difference is real is supported by James (1951) who described thirty-three cases (9·3 per cent) of infantile idiopathic scoliosis (age group 0–3) in a total series of 353 cases of scoliosis. It seems that in America this particular type of scoliosis is either rare, incompletely recognised, or confused with congenital scoliosis. It seems unlikely that it exists unrecognised because in our series the average age at diagnosis was only fifteen months, and in the American series reproduced above scoliosis with an onset before the age of five years represented only 1 per

* The Lord Nuffield Scholar in Orthopaedic Surgery 1952–53.

cent of the total. To label this type congenital scoliosis would be incorrect, because in no case were there congenital defects visible on radiographs, and as will be shown later the rates of progression are significantly different.

Our twenty-eight patients have been observed for an average of twelve years. Twelve patients were subjected to operations at varying ages; but since we wish to consider first

TABLE I

AGE INCIDENCE OF SCOLIOSIS

Age at onset (*years*)	Research Committee of the American Orthopaedic Association (404 cases)		Our series (218 idiopathic cases)	
	Number	Per cent	Number	Per cent
0–2	1	0·25	28	12·8
3–10	63	15·5	30	13·5
11–20	340	84·25	160	73·7

the progression of the disease exclusive of operative treatment, curve measurements after these operations have been excluded from this part of the analysis (Table II).

From this analysis we can observe several features peculiar to this type of scoliosis. 1) There is no sex differentiation, which is in contrast to scoliosis starting after the age of two,

TABLE II

ANALYSIS OF TWENTY-EIGHT CASES OF PROGRESSIVE INFANTILE IDIOPATHIC SCOLIOSIS

14 males. 14 females

Thoracic curve	25
Thoraco-lumbar curve	3
Proportion of cases with apex to left	93 per cent
Shortest curve	3 vertebrae
Longest curve	8 vertebrae
Average number of vertebrae in major curve	5
Average age at diagnosis	15 months

Site of apex of major curve:

T.6–7	1 case	T.9–10	2 cases
T.8	6 cases	T.10	1 case
T.8–9	7 cases	T.11	1 case
T.9	9 cases	T.12	1 case

Apex of curve was at T.8, T.8–9, T.9 in 23 of 28 cases (78 per cent)

in which girls are affected more commonly than boys in the ratio of seven to three. James (1951) found that boys outnumbered girls by two to one. 2) The curve pattern is almost exclusively thoracic. After the age of two only one-third of all significant curves are thoracic. 3) The apex of the curve is to the left in 93 per cent of patients, whereas in thoracic scoliosis occurring after the age of two the apex is to the right in 85 per cent.

Individually these differences may be of little significance, but collectively they are striking, and they tend to confirm that infantile idiopathic scoliosis is distinct from scoliosis starting after the age of two.

Progression—In considering the rate of progression of a scoliosis it is convenient to use graphic analysis. The measurement of the major curve is plotted on the vertical axis, against

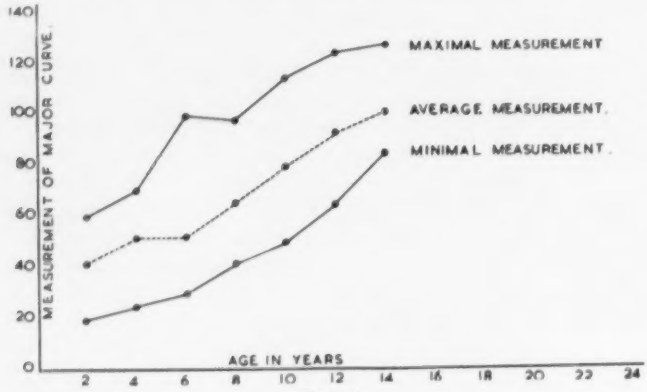

FIG. 1

Graph showing the greatest, least and average major curve measurements in twenty-eight cases of progressive idiopathic scoliosis between the ages of two and fourteen.

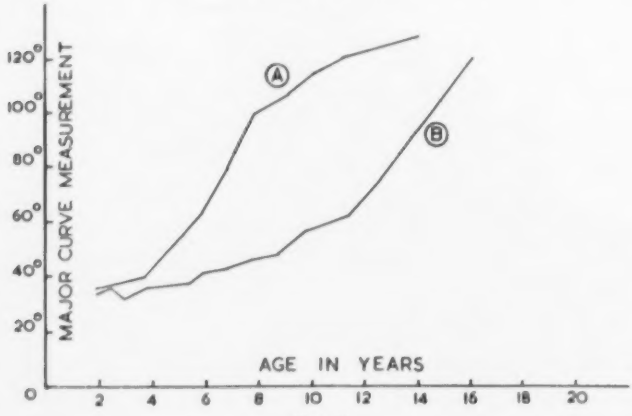

FIG. 2

Progression graphs of two infantile idiopathic curves, (A) with early onset of deterioration, and (B) with delayed onset.

the age of the patient on the horizontal axis. These graphs are of great value because they give an immediate picture of the progress of a patient.

A composite graph representing the progression of the twenty-eight patients has been constructed. It shows the greatest and least measurements of all curves at a particular age; and from the statistical analysis we have determined an average progression graph of all our patients between the age of two and fourteen years (Fig. 1).

The composite progression graph seems to demonstrate that, on average, a patient with infantile idiopathic scoliosis with an initial curve of 30 degrees will deteriorate by about 5 degrees per year and that at the age of fourteen a major curve of about 100 degrees can be expected. But from the analysis of individual cases it seems that there is considerable

FIG. 3

FIG. 4

FIG. 5

Radiographs of patient (A) in Figure 2. Figure 3—at age two years. Figure 4—At age eight years. Figure 5—At age thirteen years.

variation in the age at which deterioration starts, as distinct from the age at which the curve is first recognised. Deterioration may take place rapidly and continuously from the age of onset, or the curve may remain stationary for several years before deterioration starts. During this quiescent period there may be minor fluctuations in curve measurements, due to the mobility of the curve in young children and to error in curve measurement (Figs. 2 to 9).

FIG. 6

FIG. 7

FIG. 8

FIG. 9

Radiographs of patient (B) in Figure 2. Figure 6—At age two and a half years. Figure 7—At age six. Figure 8—At age ten. Figure 9—At age sixteen. No deterioration has occurred between the ages of two and six. Despite this delayed onset the final deformity resembles that of patient (A) (Figs. 3 to 5).

At whatever age the major curve starts to increase, the rate of progression remains fairly constant until growth ceases, though in some cases, with deterioration from an early age, the greatest deformity may be reached even before the end of the growth period. In most patients there is further slight deterioration up to the age of twenty, possibly from secondary bone moulding.

Fourteen patients have been followed to maturity, by which time all had severe deformities with the curves measuring an average of 120 degrees. The smallest curve measurement in an untreated patient was 84 degrees at the age of eighteen; by the age of twenty-seven this had become 96 degrees (Figs. 10 and 11).

Of the remaining fourteen patients who have not yet reached maturity, many have severe deformities. At the age of six the average curve measurement is 65 degrees, including five children with curves over 80 degrees, the greatest being 112 degrees (Figs. 12 to 14). With one exception the curves appear to be progressing in the manner described. The

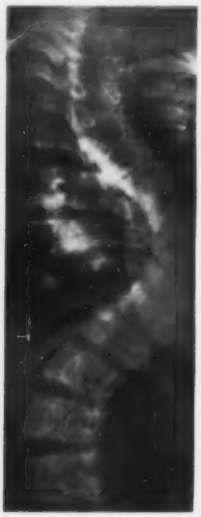

FIG. 10

FIG. 11

Untreated progressive infantile idiopathic scoliosis. Radiographs taken at age eighteen (Fig. 10) and at age twenty-seven (Fig. 11). Note the deterioration even after the age of eighteen.

exception is a child who at the age of one year had a 20 degrees' curve; at four and a half years the curve measured 45 degrees and presented the typical appearance of progressive infantile idiopathic scoliosis. This child is now nine years old, and during the past four years no deterioration has occurred; in fact the curve measurement is a few degrees less. This curve appears to be truly non-progressive. It is still possible that further deterioration will take place; but as the boy's height has increased about 3½ inches in the past twenty months this seems unlikely (Figs. 15 to 17).

The clinical picture—Although radiographic analysis offers a convenient method of observing the progression of a curve, it helps less in the assessment of the patient: this must be done by careful clinical examination, for among different patients there is considerable variation in the deformity, particularly in the shape and size of the thorax relative to the rest of the body. The spinal deformity when fully developed may vary from what is essentially a kyphosis with little lateral curve or rib distortion, to a severe lateral curvature with little kyphosis and gross rib deformity, producing the classical "keel" or "razor" back. In most, the

thoracic cage is small, with serious reduction in vital capacity. Occasionally, despite a severe curve, the thorax is well developed, and the patient able to lead a normal life (Figs. 18 and 19).

The main factors in these clinical variations are: 1) the length of the major curve;

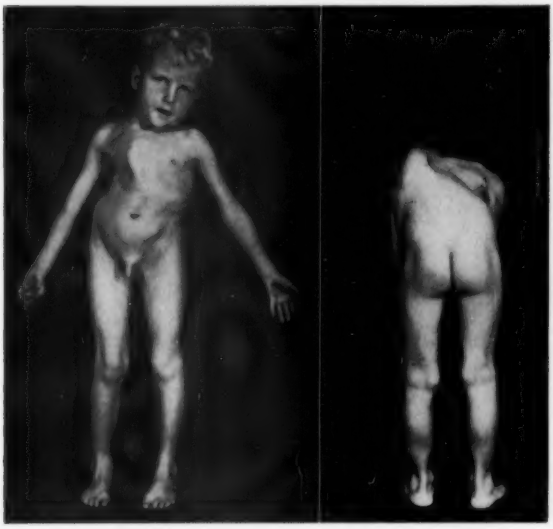

FIG. 12

FIG. 13

FIG. 14

Progressive infantile idiopathic scoliosis with a severe curve measuring 112 degrees at the age of six years.

FIG. 15

FIG. 16

FIG. 17

Non-progressive infantile idiopathic scoliosis—the only one in the series. Figure 15—At age one year. Figure 16—At age four and a half. Figure 17—At age nine and a half.

2) the degree of rotation of the vertebrae at the apex of the curve; 3) the age at which deterioration starts; and 4) the rate of deterioration. These factors appear to be to some extent interrelated. For instance, the degree of vertebral rotation is usually more severe

in short curves, and these tend to progress from an early age. But, while the rate of deterioration varies, it does not appear to be influenced by the age at which deterioration starts. It is not possible to isolate any single factor as mainly responsible in determining prognosis; but in general the type of deformity is determined by the length of the curve and degree of rotation, and the severity by the age of onset of progression and the rate; both these factors influence the degree of disability and therefore the prognosis.

The shortest curve in this series consisted of three vertebrae, and from the earliest radiographs it was evident that, despite a comparatively slight lateral curve, there was pronounced rotation of the affected vertebrae (Figs. 20 to 22). As the curve progressed

FIG. 18

FIG. 19

Progressive infantile idiopathic scoliosis. Patient aged twenty-five. Despite the severe curve the thorax is well developed. This is one of the longest curves in the series.

a kyphosis (of 125 degrees) developed and, although extreme vertebral rotation was visible on the radiographs, there was no significant unilateral rib hump. In the light of our present knowledge of the production of these deformities, we can only speculate on the pathological process involved; it may be that rotation is sufficiently severe to cause a lateral subluxation of the vertebral bodies at the apex of the curve, with consequent forward collapse of the spine above the lesion (Figs. 23 to 25).

In patients with long curves the total rotation deformity may be equal to that in a short curve but it is more widely distributed. As the deformity progresses a lateral curvature develops, and, though the rotational element increases, a long segment of the spine is involved, and little or no forward collapse occurs. With the relative absence of kyphosis rotation of the vertebral segment produces the classical rib deformity (Fig. 26). In most patients five vertebrae were involved and the deformity was a mixture of the two patterns described above (Fig. 27).

Disability—The greatest functional disability in this type of scoliosis arises from the thoracic deformity. The vital capacity is reduced; and cardiovascular function is impaired by the distortion and diminution in size of the thorax, and the increased fixation of the ribs. The deformity is usually worse in patients with an early onset of deterioration, for, in these, as well

as the disproportion of the thorax, the whole body may be underdeveloped, presumably because of a generalised failure of growth. In patients with a later onset of deterioration and slower rate of progression, milder deformity may occur, producing little or no functional disability.

FIG. 20

FIG. 21

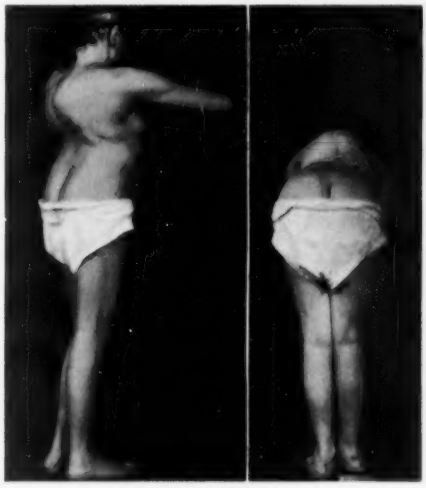

FIG. 22

Progressive infantile idiopathic scoliosis with short curve. Figure 20 shows antero-posterior and lateral radiographs at the age of three years. Figure 21 shows antero-posterior and lateral radiographs at age twenty-four and the photographs in Figure 22 were taken at the same age. In the early lateral radiograph the kyphotic element is minimal. The radiographic appearance of the spine in the later antero-posterior film is due to the severity of the kyphosis, and is typical of this type of progressive infantile scoliosis.

The cosmetic disability is usually severe and depends on decompensation and rib distortion. The degree of rotation and of kyphosis is often as great a factor as the lateral curvature. Decompensation is by no means a constant finding, as adequate compensation often occurs in the minor curves, both above and below the major curve (Fig. 28).

FIG. 23

FIG. 24

FIG. 25

A post-mortem study of a kyphoscoliotic spine. Figure 23—Antero-posterior view. Figure 24—Lateral view. Figure 25—Radiograph of the specimen. These illustrations demonstrate the term forward collapse, showing the relationship of the spine above the major curve to the column below it. Note that at the apex of the curve there is vertebral rotation through 90 degrees, and that in this area of the spine the deformity is one of lateral curvature.

FIG. 26

FIG. 27

Figure 26—Oblique photograph showing severe rib hump, with only slight increase in the normal curvature of the thoracic spine. Figure 27—Patient aged thirteen with typical kyphoscoliosis. Despite the severe curve there is little decompensation. The thoracic deformity is severe because of the early onset of deterioration. The radiographs of this patient are shown in Figures 3 to 5.

Pain, an unusual symptom in the developing curve, is relatively common later in life and may be due to a variety of causes. These include root compression, pressure of ribs on the iliac crest, and secondary degenerative arthritis.

Four of the eleven surviving patients who had reached maturity were considered to have no significant functional disability.

Mortality—There have been four deaths in the twenty-eight patients, a mortality of 14 per cent. One death followed a spine fusion operation at the age of seven, and was due to mesenteric thrombosis; the remaining three deaths—at the ages of seventeen, twenty and twenty-nine—were due to pulmonary and cardiac conditions for which the thoracic deformity could be held directly responsible.

FIG. 28

Radiograph of a patient aged thirteen showing satisfactory compensation in the secondary curves. In this case most of the compensation is occurring above the major curve.

FIG. 28

RESOLVING INFANTILE IDIOPATHIC SCOLIOSIS

Seven patients with resolving scoliosis are included in this review. This condition is probably more common than this number would suggest; but, because the deformity becomes less apparent as the infant gets older, many may not be brought for advice. This group is worthy of consideration because of the importance of differentiating it from the progressive group with regard to prognosis; and the fact that a marked curvature can exist, even for several years, and then spontaneously resolve, is of interest when considering the pathology of scoliosis. The existence of this type of infantile scoliosis may account for the successful results in the treatment of infantile scoliosis reported by Harrenstein.

The seven cases of resolving infantile scoliosis encountered in this series are analysed in Table III.

Two types of resolving infantile idiopathic scoliosis can be recognised, although probably the distinction is of interest only because of its possible bearing on the etiology: *Type* 1—The curve is shown to diminish gradually in successive radiographs until the spine is normal (Figs. 29 and 30). *Type* 2—The curve remains stationary, or even gets slightly worse for two or three years, and then quite suddenly disappears within a few months (Figs. 31 to 33).

The longest interval between the discovery of the scoliosis and the spine's becoming straight both clinically and radiologically was four and a half years, and the average time for the seven patients was two and a half years.

DIFFERENTIAL DIAGNOSIS

Classification—Scoliosis may be classified as follows: 1) Congenital abnormalities. 2) Scoliosis of known etiology: paralytic; thoracogenic; neurofibromatosis and other neurological conditions. 3) Scoliosis of unknown etiology (idiopathic): progressive; resolving.

In considering the differential diagnosis of scoliosis in the infantile group the problem is simplified by the natural exclusion of scoliosis of known etiology. Paralytic scoliosis before the age of two is uncommon, and the symptomatology is usually sufficiently evident to establish the diagnosis.

FIG. 29

FIG. 30

Resolving infantile idiopathic scoliosis, type 1. Figure 29—Radiograph at age five months. Figure 30—At age thirteen months. The apical rotation clearly visible in the early radiograph is shown corrected in the later film.

FIG. 31

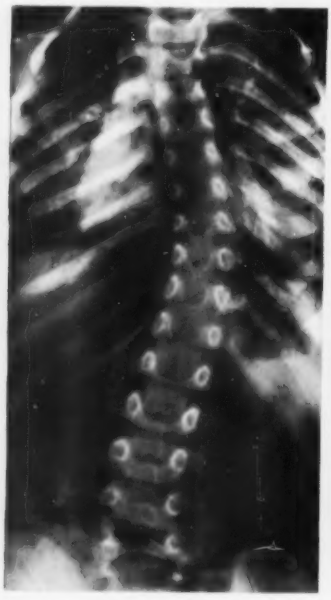

FIG. 32

FIG. 33

Resolving infantile idiopathic scoliosis, type 2. Figure 31—Radiograph at age one and a half years. Figure 32—At age three years. Figure 33—At age six and a half years. This patient had no treatment.

Likewise, scoliosis associated with neurofibromatosis is unusual at this early age. The earliest age at which a curve was observed in a patient having, or subsequently developing, other stigmata of the disease was seven years, although undoubtedly the curve had been present before this. The similarity of deformity, both clinically and radiographically, between the scoliosis of neurofibromatosis and the kyphotic type of infantile idiopathic scoliosis must cause serious consideration of whether, in fact, they represent minor variants of the same

TABLE III

ANALYSIS OF SEVEN CASES OF RESOLVING INFANTILE SCOLIOSIS

4 females. 3 males	
Average period of observation	6·2 years
Age at diagnosis	1–9 months
Average age at diagnosis	5½ months
Major curve measurements	
Less than 10 degrees	2 cases
10 to 20 degrees	3 cases
More than 20 degrees	2 cases
Apex of curve to right	2
to left	5
Longest curve	10 vertebrae
Shortest curve	5 vertebrae
Average length of curve	7½ vertebrae
Vertebral rotation observed in 4 cases	
Position of apex to curve	
T.7 1 case	T.9 3 cases
T.7–8 1 case	T.10 1 case
T.10–11 1 case	

TABLE IV

DIFFERENTIAL DIAGNOSIS OF PROGRESSIVE AND RESOLVING INFANTILE IDIOPATHIC SCOLIOSIS

	Progressive	Resolving
Average age at diagnosis	15 months	5½ months
Average number of vertebrae in major curve	5	7½
Major curve measurement	More than 20 degrees	Usually less than 20 degrees
Degree of rotation of apical vertebrae	Usually marked	Minimal

disease. We have no evidence at present of neurofibromatosis in any patient of this series; but this does not necessarily preclude its later appearance (Figs. 34 to 36).

Scoliosis secondary to congenital spinal abnormalities is relatively common, and during the period covered by this review, forty-two patients with congenital scoliosis have been treated at this hospital, representing 15 per cent of all those with progressive curves. The average age at diagnosis in this group was eleven years, and in only seven infants was the curve noticed before the age of one year. The diagnosis of congenital scoliosis is made from radiographs, in which the defects are clearly visible in infancy and adolescence (Fig. 37).

In later life the radiographic appearances tend to be confusing because of secondary structural changes, and it may be difficult to distinguish a congenital from an idiopathic scoliosis.

FIG. 34

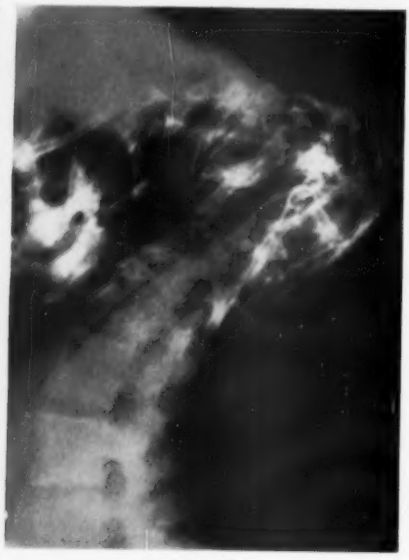

FIG. 35

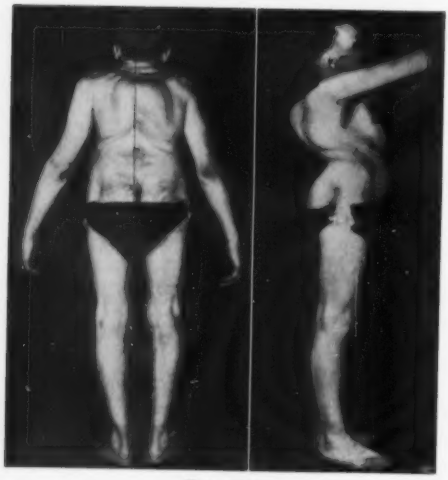

FIG. 36

Scoliosis associated with subcutaneous neurofibromatous nodules. Figure 34—Antero-posterior radiograph. Figure 35—Lateral radiograph. Note the similarity of the deformity and radiographic appearance with the kyphotic type of progressive infantile idiopathic scoliosis (see Figs. 20 to 22).

Conversely, in a long-standing severe idiopathic curvature secondary effects occur, such as fusion of the laminae, which may lead to the erroneous diagnosis of congenital scoliosis.

In this series of twenty-eight cases of infantile idiopathic scoliosis there was no evidence of congenital defects of the thoracic spine. It has been suggested that congenital abnormalities may be present in these curves but insufficiently severe to be seen on radiographs.

The average rate of progression of congenital scoliosis is much below that of progressive infantile idiopathic scoliosis. In forty-two cases of congenital scoliosis analysed the average rate of progression was 2 degrees a year, compared with 5 degrees in progressive infantile idiopathic scoliosis (Fig. 38). This significant difference suggests that infantile idiopathic scoliosis is a separate entity from congenital scoliosis. With the exclusion of congenital scoliosis and scoliosis of known etiology, the differential diagnosis remains between progressive and resolving idiopathic scoliosis: this may be difficult and the diagnosis may be in doubt up to the age of three years. There are, however, some points that may help in differentiating these two types (Table IV).

FIG. 37

Radiograph showing typical congenital abnormalities. The hemivertebra, rib defects and fusion of laminae are clearly visible, and prevent confusion with idiopathic scoliosis.

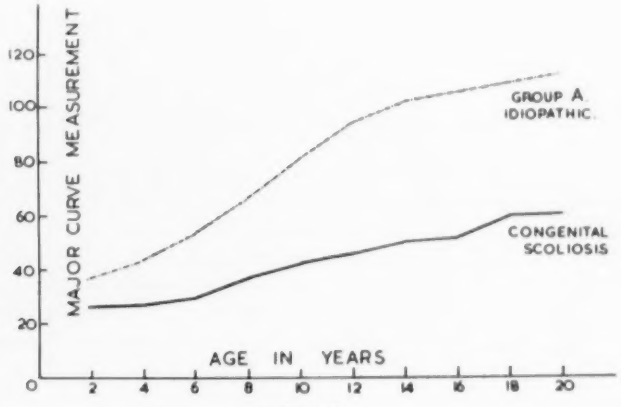

FIG. 38

Graph showing the average progression of known cases of congenital scoliosis (forty-two cases), compared with that of progressive infantile idiopathic scoliosis.

SUMMARY

1. The natural history and prognosis of progressive infantile idiopathic scoliosis are reviewed and twenty-eight cases are reported.

2. Resolving infantile idiopathic scoliosis is described and seven cases are reported.

3. The length of the curve, the degree of rotation, the age of onset of deterioration, and the rate of progression are the important factors in determining the type and severity of the deformity.

4. Infantile idiopathic scoliosis is briefly compared with congenital scoliosis.

We wish to thank all members of the Staff of the Wingfield, who by their agreement to the continued concentration of all patients with scoliosis have made the long-term review of the subject possible, and in particular Professor Trueta for many helpful suggestions. We also wish to acknowledge the help and inspiration of the late Mr G. R. Girdlestone who made possible the commencement of this study. We are also indebted to Miss Robins of the X-ray Department, and Miss Bird, Clinical Photographer, for their help and co-operation.

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KYPHOSCOLIOSIS

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In ordinary structural scoliosis there is rotation of the vertebral bodies but no alteration of the vertebral column in an antero-posterior direction. At operation the appearance of the full length of the primary curve in approximately 150 patients confirms this statement. Only when the vertebral position is thus visualised is it possible to estimate the effect of rib rotation, which so frequently gives the impression of a kyphosis as well as lateral curvature, especially when rotation of the vertebral bodies approaches 90 degrees.

The term kyphoscoliosis has been used frequently but loosely to describe an effect due to rib rotation without determining whether a kyphosis was in fact present. The purpose of this paper is to describe a number of cases of varying etiology in which there is true vertebral kyphosis and lateral curvature with rotation—kyphoscoliosis in a true anatomical sense.

Kyphosis associated with structural lateral curvature as the equal or even dominant deformity is not discussed in the English literature. Bingold (1953) in a recent paper described three cases of congenital kyphosis at the thoraco-lumbar junction. These are comparable to several of the cases discussed but were not severe deformities and were not associated with scoliosis. The French literature has but a few reports. However, in Germany the condition has been the subject of a number of lengthy and beautifully illustrated papers.

Thirty-one patients seen at the Royal National Orthopaedic Hospital are available for review. Two further cases are included which are acknowledged later.

Differential diagnosis of kyphoscoliosis. *Kyphosis*—True kyphosis in the age group under discussion is commonly due to tuberculosis or Scheuermann's osteochondritis. Tuberculosis characteristically produces kyphosis; there may be lateral angulation, but there is neither true lateral curvature nor rotation. A number of the cases to be described had previously been diagnosed as tuberculosis.

TABLE I

Etiology of Kyphoscoliosis

Type		Number of cases
Congenital	Confirmed	16
	Suspected	5
Infantile idiopathic scoliosis with kyphosis		10
Neurofibromatosis		2

Adolescent kyphosis is characterised by a long gradual kyphosis; there may be a slight degree of scoliosis, usually with two structural curves. In true kyphoscoliosis the area of kyphosis is very short and in no way comparable to an epiphysitis.

Scoliosis—The lateral radiograph of a scoliotic spine of any etiology may show apparent antero-posterior deformity. Somerville (1952) demonstrated that there might be an initial lordosis. When rotation is gross a lateral radiograph shows an oblique view of the vertebral

column and a long kyphosis may seem to be present. The apex of a true kyphoscoliosis, however, rarely involves more than two or three vertebrae, and is angular.

The combined deformities of kyphosis, lateral curvature, and rotation produce overlap with resultant ill defined bone detail. When such vertebral "confusion" is seen in an antero-posterior radiograph in which the ribs and pelvis have normal definition, kyphoscoliosis should be suspected. Scoliosis shows a smooth curve; when this becomes angular or "squared," and if there is one clear disc space, kyphoscoliosis should be suspected (Figs. 5, 14, 17).

Etiology of kyphoscoliosis—The cases reported fall into three etiological groups, as shown in Table I.

CONGENITAL KYPHOSCOLIOSIS

Congenital skeletal abnormality is the cause, and the diagnosis cannot be accepted without radiological proof of this. Congenital wedging, vertebral fusion, hemivertebrae, absent vertebral bodies, spina bifida and rib anomalies were present. A number of patients were seen as adults with gross deformity; early radiographs were not available, and congenital

TABLE II

CONGENITAL KYPHOSCOLIOSIS (TWENTY-ONE CASES)

Level of deformity		Number of cases
Thoraco-lumbar	Congenital	13
	Congenital suspected	3
Cervico-thoracic	Congenital	3
	Congenital suspected	2
Total		21
Thoraco-lumbar kyphoscoliosis with paraplegia		2
Cervico-thoracic kyphoscoliosis with paraplegia		3

anomaly could not be demonstrated in the hopelessly confused vertebral pattern shown in recent radiographs. They were in all other respects the same as the proven cases.

Congenital kyphoscoliosis occurred at two levels, thoraco-lumbar and cervico-thoracic. Paraplegia occurred at both levels (Table II).

CONGENITAL THORACO-LUMBAR KYPHOSCOLIOSIS

Pathology—The congenital anomalies which lead to this deformity are obscure, as few patients have adequate early radiographs. There is first of all the curious predilection for the low thoracic and thoraco-lumbar region. In several cases it seemed that two or three vertebrae were fused together; absence of the vertebral body epiphyses with deficient anterior growth may then have produced the kyphosis. This may be true because the major development of the deformity occurred during the period of rapid growth in the pre-puberty years. At operation one patient was found to have unilateral spina bifida, with fusion of the laminae on the other side; in other patients anomalies of the laminae were seen at operation.

Clinical examination—The condition may simulate kyphosis or scoliosis, particularly the latter. The photographs show the typical appearance, and with practice this can be recognised. The antero-posterior radiograph may give the first hint that there is kyphosis as well as scoliosis.

Prognosis—The prognosis must be considered from two aspects. Congenital lesions of the thoraco-lumbar region are not uncommon, whereas kyphoscoliosis is rare; it is not yet possible to appreciate the significant prognostic factors in the development of kyphosis. When kyphoscoliosis has developed, it seems that there is every likelihood of a severe and progressive deformity. Twelve patients have a kyphosis of more than 90 degrees, three have only small deformities (Fig. 1). A baby with an absent first lumbar vertebral body has already developed a severe kyphosis (Fig. 2). The degree of deformity can be remarkable, the two limbs of the kyphotic spine becoming almost parallel (Case 1, Fig. 5). The possibility of paraplegia will be discussed later.

FIG. 1

FIG. 2

Figure 1—A small congenital kyphosis with three fused vertebrae; one of three cases which did not progress. Figure 2—Lateral radiograph showing absent first lumbar vertebral body; the kyphosis is progressive.

Treatment—Treatment of these deformities has always in the first instance been conservative; it was not of great value. Kyphoscoliosis is a difficult deformity to correct because of the three planes in which deformity occurs. The Risser jacket has not proved effective; the distracting plaster jacket is better but still the kyphosis is obstinate. Most of these patients have been seen late, but it has been thought worth while to correct and fuse the spines of five of them for deformity. In view of the difficulty of correction and, in this series, the severity of the untreated deformity, it would seem wise to fuse the spine earlier. Early fusion of the spine in the treatment of Pott's disease and scoliosis is theoretically unwise because it may produce lordosis by arresting growth posteriorly; in kyphoscoliosis it would be advantageous if this did occur.

The degree of kyphosis is measured by drawing lines parallel to the anterior borders of the vertebral bodies of each limb and measuring the angle.

Case Reports

Case 1—Curvature developed in a girl of twelve years, but radiographs then showed a barely noticeable kyphosis (Fig. 3). Eighteen months later there was a gross left thoraco-lumbar

FIG. 3

FIG. 4

Case I. Figure 3—Kyphosis of 68 degrees. Figure 4—Photograph of patient eighteen months later.

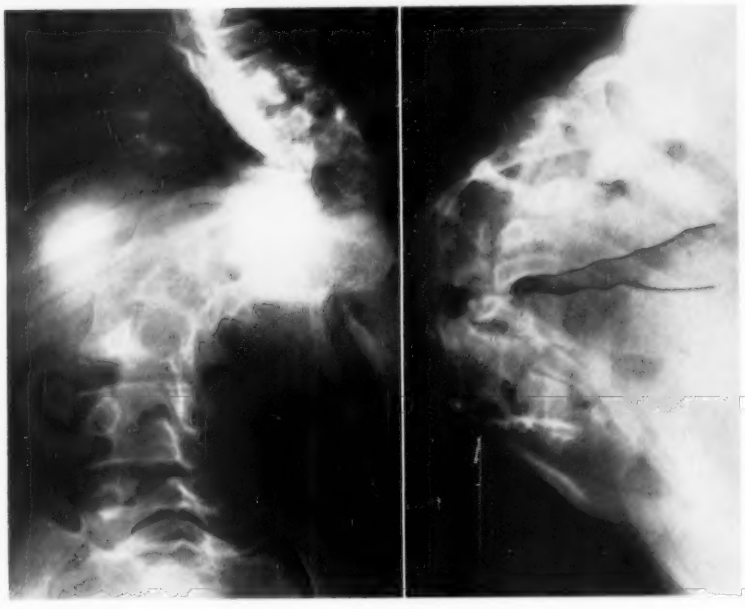

FIG. 5

Case I—The left scoliotic curve is not smooth but angular; the kyphosis is extreme. Bone detail is characteristically confused at the deformity although elsewhere clear definition is achieved.

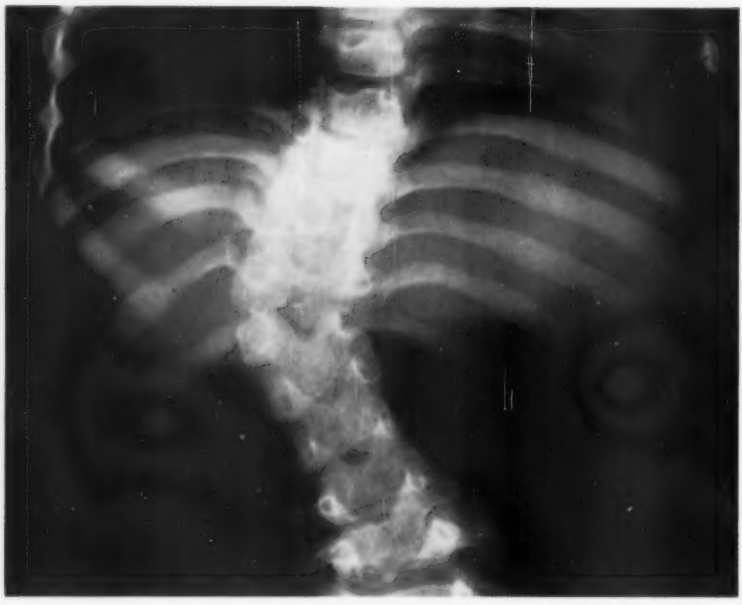

FIG. 6

Case 2—Age five years. Congenital defects are seen at T.11–12.

FIG. 7

FIG. 8

Case 2. Figure 7—Photograph of the patient at age seventeen. The lateral radiograph (Fig. 8) shows a kyphosis of 125 degrees. There was a scoliosis to the right of 70 degrees.

kyphoscoliosis (Figs. 4 and 5). The lateral radiograph showed the kyphosis to be so gross, measuring 150 degrees, that the two limbs of the vertebral column were almost touching. Despite this there was no involvement of the cord. The apex of the kyphosis lay between T.9 and T.12. After attempted correction in an antero-posterior Risser jacket, fusion was performed. It was then seen that the two laminae above the apex were fused together and likewise those below. On the left, parts of the laminae were missing and a meningocele was present. The deformity has remained unchanged since operation.

Case 2—A girl was noticed to have a curvature of the spine at the age of ten days. Subsequently she spent eight years in plaster beds (Fig. 6) but despite this the curvature became worse. When seen again at seventeen she had a severe right thoraco-lumbar kyphoscoliosis (Figs. 7 and 8). There were no cord changes. As she was fully grown no intervention was necessary, correction being impossible and no deterioration being expected.

Case 3—A curvature had been noticed two weeks after birth and it steadily increased in a girl now eight years old. She had some spastic changes in the left leg, not progressive, and ascribed

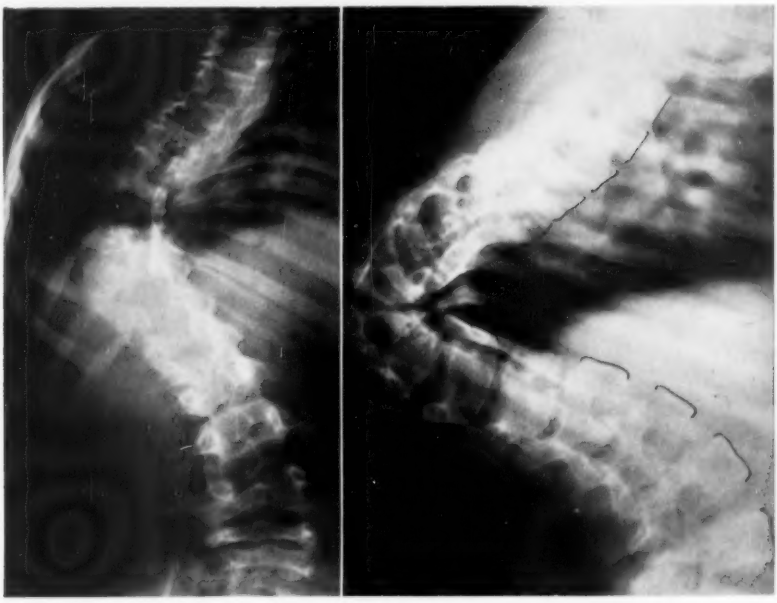

FIG. 9

Case 3—Scoliosis of 70 degrees and kyphosis of 132 degrees.

by a neurologist to cerebral cortical changes. She also had congenital absence of the abductor pollicis brevis and opponens pollicis muscles on the left. The apex of the kyphosis was low thoracic, probably T.9. On the left were fifteen ribs, on the right thirteen (Fig. 9).

Because of her age there was reason to expect an increase of the deformity, and, because of the slight doubt as to spinal cord compression, fusion was performed. Correction on this occasion, and since, has been carried out by the distraction jacket. It proved effective within the limits expected when dealing with a congenital bony abnormality.

CONGENITAL CERVICO-THORACIC KYPHOSCOLIOSIS

The site of this deformity is in the upper thoracic spine, but as one limb of the kyphosis is the cervical spine it seems appropriate to use this term. Congenital anomalies are present and have included fusion of vertebral bodies, hemivertebrae and rib anomalies. Three of the five cases had acceptable evidence of congenital anomaly; early radiographs were not available in the other two.

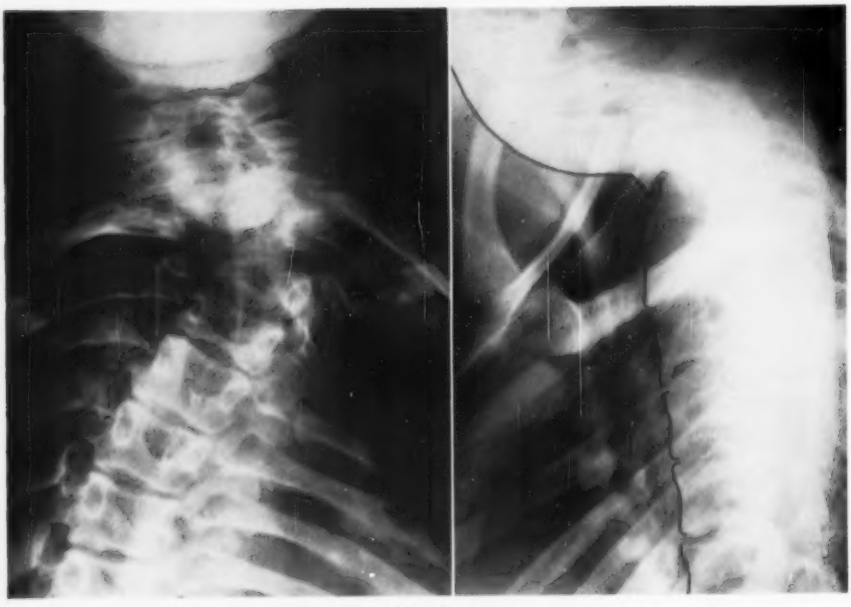

FIG. 10

Case 4—Antero-posterior radiograph shows right scoliosis. The lateral film shows kyphosis of 90 degrees. There is fusion of thoracic vertebrae 2–3.

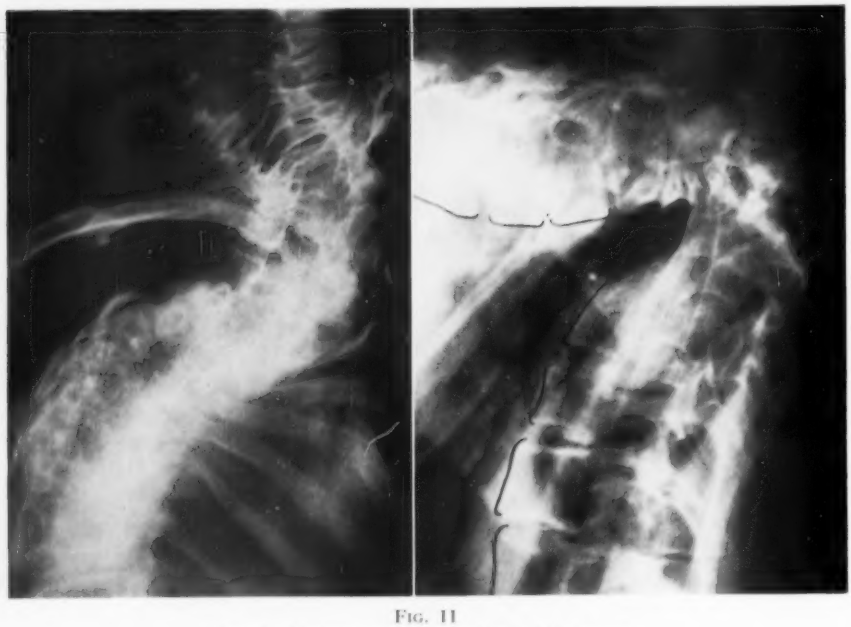

FIG. 11

Case 5—Moderate scoliosis; kyphosis 140 degrees.

There is remarkably little visible deformity; even with a 90 degrees' kyphosis there is no more than a marked "dowager's hump." The upper margin of the trapezius may be elevated if scoliosis with rotation is marked.

Prognosis would appear not to differ from that of deformities occurring at the lower level. All five patients had a kyphosis of more than 90 degrees; the scoliosis varied. Three developed paraplegia. Congenital upper thoracic scoliosis without kyphosis is common, and the factor which determines kyphosis is not known; the serious consequences when kyphosis is present are, however, apparent. Treatment by correction in a distraction jacket followed by fusion is suggested.

Case Reports

Case 4—A girl now aged fifteen years developed curvature at two years. She had a severe right-sided high thoracic kyphoscoliosis. Stereoscopic radiographs showed fusion of T.2–3, and there are eleven ribs on the right, twelve on the left (Fig. 10).

Case 5—A girl developed a curvature at one year of age. She now has a kyphosis of 140 degrees (Fig. 11). No congenital defect can be seen but the radiographs are difficult to interpret and no early ones are available.

CONGENITAL KYPHOSCOLIOSIS WITH PARAPLEGIA

Among seventeen patients with severe deformities, five had paraplegia, three at the upper level, two at the lower. In four cases the primary abnormality was proved at operation to be a congenital skeletal anomaly; in all four, pressure on the cord arose from an anterior ridge of bone. All of them had a severe kyphoscoliosis, though some patients without paraplegia had worse deformities. In four patients the paraplegia developed in the later years of growth; in the fifth patient the history is not well recalled but from the age of two there was difficulty with walking (Case 6).

Treatment of the paraplegia was not considered necessary in one patient (Case 6). In the other patients transposition of the cord was carried out by a posterior approach (two cases) or by antero-lateral decompression (two cases). The first method gave success, but two years after operation in both there was a recurrence probably due to increasing deformity. In each case a distraction jacket relieved the recurrent paraplegia, and fusion, one posterior, one anterior, has been performed. The antero-lateral approach gave one success, one failure.

FIG. 12

Case 6—This lateral radiograph shows a right-angled kyphosis. There are four or five vertebrae fused in the apical mass.

Case Reports

Case 6—A woman of thirty-seven stated that since the age of two years she had experienced difficulty in walking, and that this was now becoming worse. She had an upper thoracic kyphosis, clinically not gross, and a spastic left leg with gross adduction and equinus. After investigation it was thought probable that her increasing difficulty was due to the leg deformities rather than to progressive cord pressure (Fig. 12).

Case 7—A young man with a high thoracic scoliosis developed paraplegia at the age of nineteen, with a sensory level at the fourth thoracic segment (Fig. 13). A forward transposition of the cord

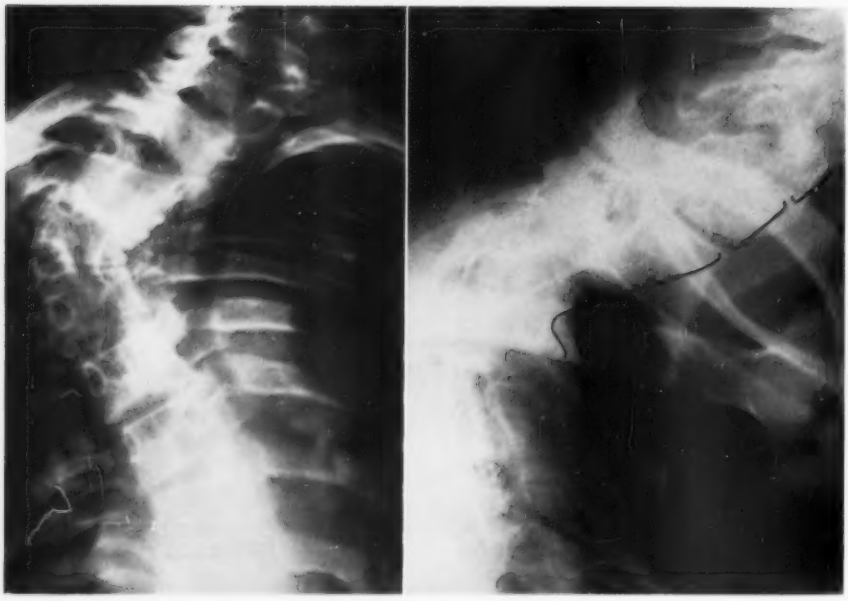

FIG. 13

Case 7—Congenital kyphoscoliosis with paraplegia. Congenital lesions confirmed at operation.

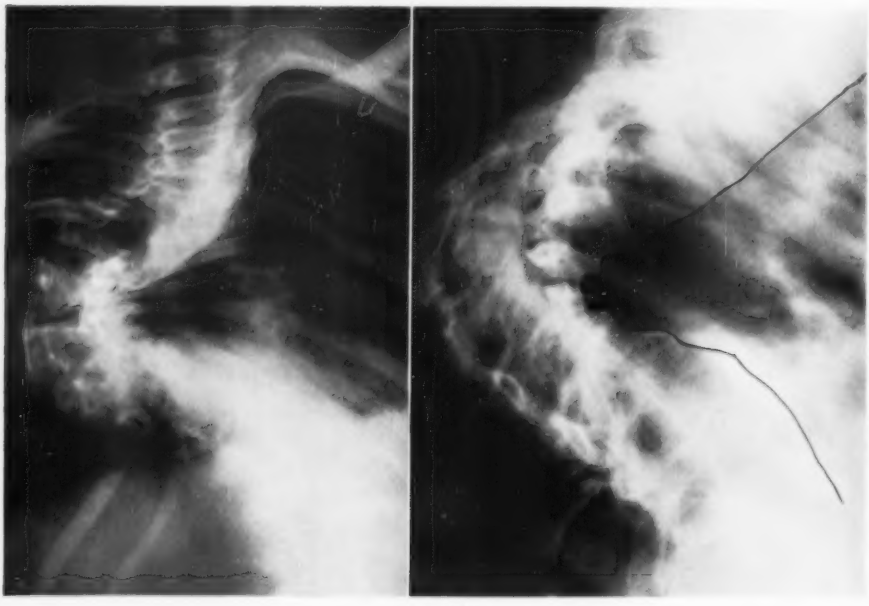

FIG. 14

Case 8—Left scoliosis, showing clear disc at apex and "squared" curve. Lateral radiograph shows kyphosis of 130 degrees.

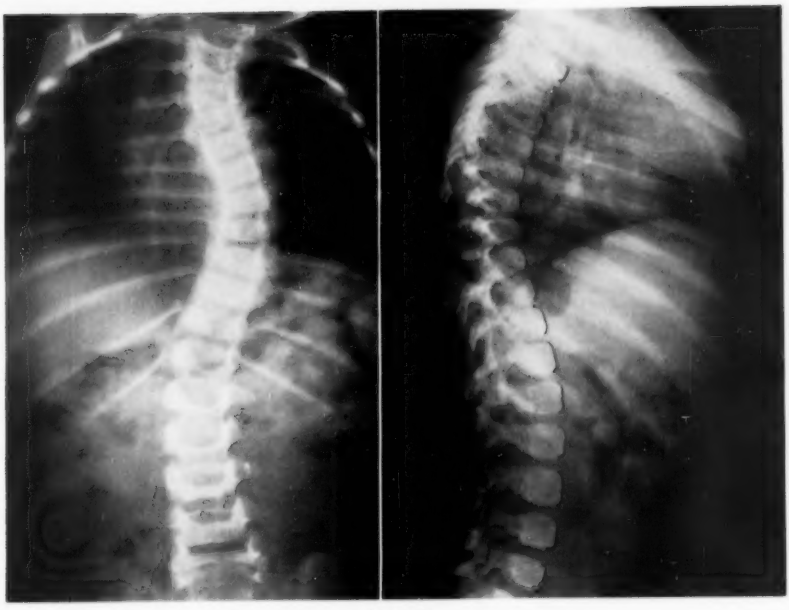

FIG. 15

Case 9—Idiopathic kyphoscoliosis. Early radiographs show no skeletal anomaly and no kyphosis.

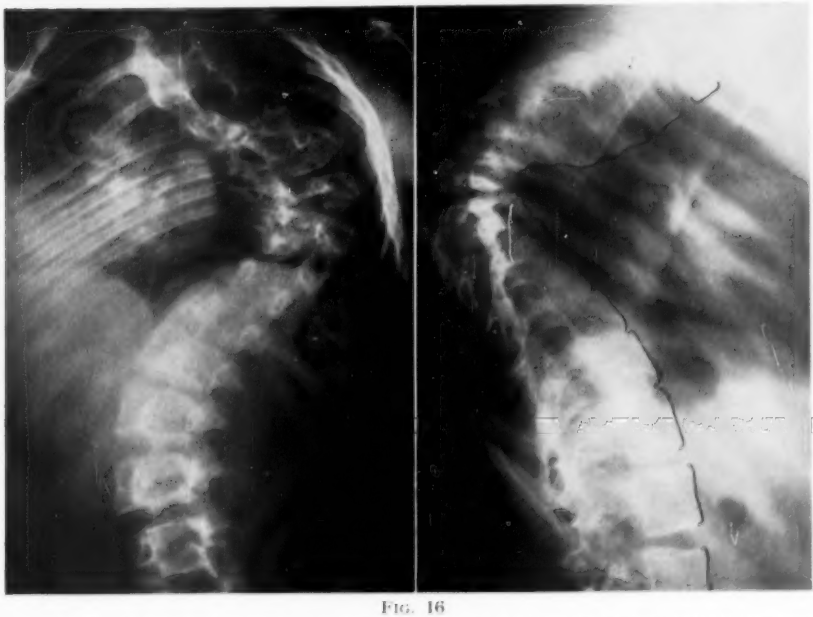

FIG. 16

Case 9—The deformity has increased. The lateral curve is becoming angular and the kyphosis marked.

was carried out; relapse of the paraplegia occurred, but was relieved by incision of the dura two months after the first operation. Three years later he again developed paraplegia, which steadily increased. Radiographs showed the upper limb of the kyphosis to be at a right angle to the lower, and displaced downwards. A distraction jacket completely relieved the paraplegia. Owing to the original extensive laminectomy posterior fusion would have been difficult. A rib graft was therefore placed on the antero-lateral aspect of T.1–4 at the junction of the two limbs of the kyphos.

Case 8—A young man aged nineteen was referred to Mr H. J. Seddon with a "tuberculous paraplegia" of two years' duration. Radiographs showed no evidence of tuberculosis. They did, however, present appearances identical with those already seen (Fig. 14). These radiographs do not demonstrate congenital abnormality, but at operation a massive congenital fusion was found in an antero-lateral approach for transposition of the cord, which resulted in excellent recovery. The cord pressure arose from an anterior ridge of bone.

IDIOPATHIC KYPHOSCOLIOSIS

Because of the interest aroused by these congenital anomalies and by Somerville's work on lordosis in idiopathic scoliosis, a more careful study of the lateral radiographs of all our patients with scoliosis has been undertaken, with the unexpected finding of a number of patients with severe idiopathic kyphoscoliosis.

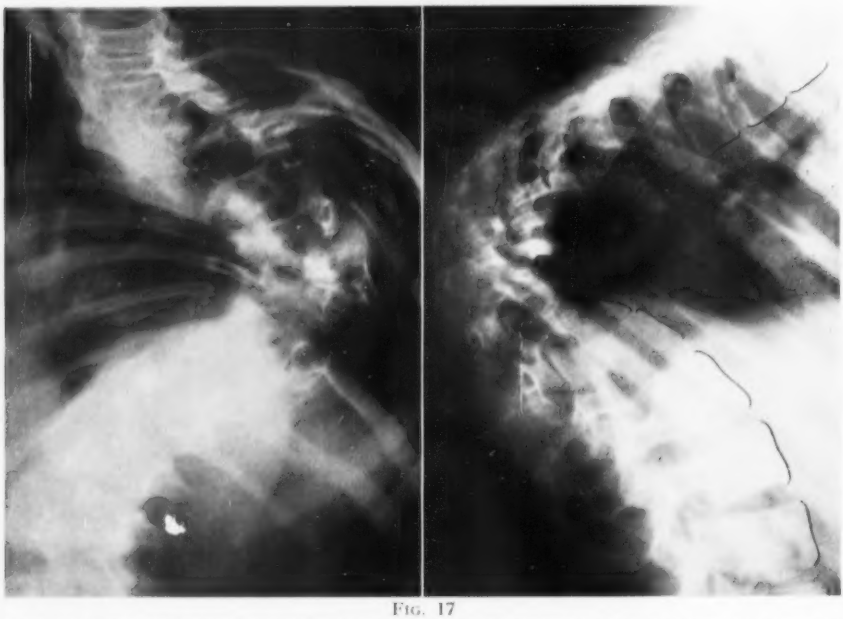

FIG. 17

Case 10—The antero-posterior radiograph shows the confused bone detail and irregular curve of kyphoscoliosis. The lateral radiograph shows a severe kyphosis.

Examples have been seen only among the group of infantile idiopathic curves. These curves, by definition, commence before the age of three and the radiograph must exclude congenital skeletal anomalies. This pattern of scoliosis is found only in the thoracic region. Some seventy children have been observed with this type of scoliosis, ten of whom have developed additionally a kyphosis, although early radiographs showed no gibbus. Operation has confirmed the presence of kyphosis, and the absence of posterior congenital anomalies. The usual site is mid-thoracic. Clinically suspicion is aroused by the increased deformity, roundness of the back and short stature. Radiologically the bone detail becomes confused, and the curve is no longer the arc of a circle but becomes angular or squared as the two limbs of the spine become more horizontal.

Kyphosis has only been seen in the severest examples of idiopathic infantile thoracic scoliosis. The prognosis of the whole group is poor, but with the additional deformity it is usual to find a scoliosis and a kyphosis each of 100 degrees or more. Paraplegia has not been seen.

Treatment is similar to that advised for congenital kyphoscoliosis: correction by distraction and fusion. The deformity may be gross as early as five or six years of age. It is then perhaps wise to delay fusion. The Milwaukee jacket devised by Blount has been useful in preventing further deformity.

Case Reports

Case 9—A girl now aged eight developed infantile idiopathic left thoracic scoliosis when aged three months. Early radiographs showed no congenital defect or kyphosis (Fig. 15). At four years of age kyphosis was first noted. The deformity became severe, a scoliosis of 92 degrees and a kyphosis of 130 degrees being present at seven years of age (Fig. 16). Because of the kyphosis correction was carried out by a distraction jacket and fusion. There was no congenital anomaly of the laminae at operation.

Case 10—A boy now aged eleven years developed infantile idiopathic thoracic scoliosis at the age of eight months. Early radiographs showed no evidence of a congenital defect, but kyphosis was noticeable when this boy first attended two years ago. Correction and fusion were carried out; at operation no abnormality of the laminae was noted (Fig. 17).

KYPHOSCOLIOSIS IN NEUROFIBROMATOSIS

One high thoracic and one thoraco-lumbar kyphoscoliosis have been seen in two girls. In both the deformity was severe. The characteristic pigmented skin patches were present. Kyphoscoliosis in neurofibromatosis is well recognised, and is mentioned only to recall its existence when the differential diagnosis is considered.

SUMMARY

1. The true deformity of kyphoscoliosis has received little attention. Twenty-one deformities of congenital origin, ten idiopathic, and two secondary to neurofibromatosis, are discussed. The diagnosis is established and usually first suspected by radiography.

2. The deformity was severe and progressive except in three cases; paraplegia occurred in five congenital cases.

3. Early correction and fusion are advocated in the hope of preventing paraplegia and because correction of the old-established deformity is difficult or impossible.

Mr A. L. Eyre-Brook, Mr D. Lloyd Griffiths and Mr H. J. Seddon have been kind enough to allow me to include three cases under their care. I would like to thank the many surgeons who have referred cases to the scoliosis clinic. I would thank Mr R. J. Whitley for his skilled help with the radiographs which are, from the nature of the deformity, difficult to reproduce.

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FRACTURES OF THE TIBIAL CONDYLES

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Fractures of the tibial condyles, involving as they do weight-bearing articular surfaces and important soft tissues such as ligaments and semilunar cartilages, present a variety of problems in treatment and prognosis. Most opinions previously expressed in the literature have been in favour of operative reduction in most cases (Cubbins, Conley, Callahan and Scuderi 1934, Leadbetter and Hand 1940, Buckner 1941, Cave 1948, Palmer 1951) on the grounds that anatomical reduction is the primary aim of treatment and that this can more often be achieved by open reduction than by closed manipulation. On the other hand Cotton (1936) and Caldwell (1936) considered that operative reduction is rarely justified, and Bick (1941) used it only in cases with severe displacement.

This review of tibial condyle fractures treated during the years 1941 to 1953 was made in an attempt to assess the results of treatment, both conservative and operative. The records and radiographs of ninety-three patients with such injuries have been studied, and sixty patients attended for follow-up within the past few months.

ETIOLOGY

Fractures of the tibial condyles result either from valgus or varus strains occurring at the knee joint, from direct violence to the outer or inner aspect of the extended weight-bearing knee or from the indirect violence of a fall from a height upon the foot, transmitted up the tibial shaft to the extended knee. Valgus strains lead to fractures of the lateral tibial condyle with

TABLE I

ETIOLOGY OF TIBIAL CONDYLE INJURIES

Type of Injury	Number of cases
"Bumper" or "fender" injuries to pedestrians	17
Motor cyclists or cyclists	23
Fall from a height	24
Struck by falling objects	10
Injuries by animals	5
Football injuries	6
Miscellaneous	8
Total	93

associated damage to the medial ligament and sometimes to the anterior cruciate ligament. Varus strains, which are much less common, lead to fractures of the medial tibial condyle with associated damage to the lateral ligament and sometimes to the anterior cruciate ligament. The various causes of these injuries are shown in Table I.

There were two pathological fractures, one of a tibia affected by Paget's disease, and the other in a patient with severe rheumatoid arthritis.

Age incidence—The incidence of these injuries is twice as great in the fifth and sixth decades of life as in the third and fourth or seventh and eighth (Table II). The youngest patient in this series was twenty-three, the oldest eighty-four. There were no compound fractures.

TABLE II

AGE INCIDENCE OF TIBIAL CONDYLE INJURIES

Age . . .	21–40	41–60	61–80	81+	Total number of patients
Number of patients	23	45	24	1	93

CLASSIFICATION

A satisfactory classification is that suggested by Palmer (1951), with certain modifications. **Type I. Split fractures** (Fig. 1)—This is the least common type of tibial condyle fracture. The lateral edge of the lateral femoral condyle is driven down into the articular surface of the lateral tibial condyle, causing a wedge-shaped fragment of varying size to become split off and displaced outwards. There is seldom any downward displacement of the lateral fragment in this type of injury. The fracture is associated with sprains of the medial ligament of varying severity. Similar fractures of the medial tibial condyle with sprains of the lateral ligament occurred in four of the seven patients with Type I fractures. These were the only medial condyle injuries in the series after fractures of both condyles (Type III) had been excluded.

FIG. 1

Type I (split) fracture, without marked displacement.

Type II. Compression fractures—These injuries appear to be produced by the blunt inferior articular surface of the femoral condyle, which is driven into the articular surface of the opposing tibial condyle—acting like a hammer in contrast to the chisel-like action of the outer edge of the femoral condyle in the production of the Type I fractures. The displacement caused by this injury ranges from depression of the anterior, posterior, lateral or medial parts of the plateau with comminution of the area (Figs. 2 to 5), to depression of the whole condyle, the fracture line passing from the non-articular region of the tibial spine to the base of the condyle (Fig. 6). This latter type is associated with a fracture of the head or neck of the fibula when the lateral condyle is the seat of the injury.

In one variety the treatment and prognosis differ from that of the remainder of this group. Here a large lateral fragment is split off and displaced outwards, whereas the central and medial part of the articular surface is comminuted and depressed obliquely downwards and inwards (Fig. 7). Frequently fragments from the central part of the articular surface are driven downwards and wedged in the split between the major fragments. This fracture is usually associated with damage to the collateral and anterior cruciate ligaments. The semilunar cartilage is often torn and displaced, and may be driven down into the fracture line. This injury is a combination of Types I and II.

FIG. 2

FIG. 3

Type II (compression) fractures. Figure 2—Depression of lateral part of plateau. Figure 3—Depression of central and medial part of plateau.

FIG. 4

FIG. 5

Type II (compression) fracture with depression of antero-medial part of plateau. Figure 4—Before treatment. Figure 5—after manipulation.

FIG. 6

Type II (compression) fracture with depression of whole lateral condyle.

FIG. 7

Fracture of lateral condyle combining the features of Types I and II.

The common feature of all these variations is the depression of part or all of the articular surface, with comminution and crushing of the subchondral layer of cancellous bone. Fracture of the head or neck of the fibula may occur in any of these varieties of compression fracture of the lateral condyle except those in which only an anterior segment of the articular surface is involved.

FIG. 8

Type III fracture (both condyles). Articular surfaces intact and minimal displacement.

Type III. T-shaped or Y-shaped fractures—In this type both lateral and medial tibial condyles are fractured. In at least thirteen of the fifteen fractures of this type the predominant force was probably a vertical one along the shafts of the long bones. There are two main varieties of this injury: 1) Both condyles are fractured and displaced outwards and downwards, each as one large fragment, and the upper tibial shaft is driven upwards in between them. Their articular surfaces appear radiologically to be undamaged (Figs. 8 and 9). 2) Both condyles are fractured and displaced outwards and downwards, but one condyle (either lateral or medial) also shows the features of a Type II compression fracture (Fig. 11), commonly the mixture of Types I and II previously described. This type of fracture tends to be more comminuted than the last.

FIG. 9

FIG. 10

Type III fracture. Articular surfaces intact but marked displacement. Figure 9—Before treatment. Figure 10—After manipulation.

FIG. 11

FIG. 12

Type III fracture with Type II (compression) fracture of lateral condyle. Figure 11—Before treatment. Figure 12—After manipulation.

TREATMENT

Treatment of Type I (split) fractures (Fig. 1)—In those in which the outward displacement of the condylar fragment is only slight, the application of a plaster cylinder, with the knee extended and held in valgus or varus, is sufficient. When displacement is more than slight the fracture is manipulated under general anaesthesia, the fragments being compressed manually or by the application of an Esmarch's bandage, and the limb immobilised in a plaster cylinder. Non-weight-bearing immobilisation is maintained for three to six weeks until union of the fracture and repair of the ligamentous damage has occurred and then, depending upon the severity of the injury, the patient either begins graduated weight-bearing exercises or performs non-weight-bearing exercises for four to six weeks before weight bearing is allowed. Quadriceps exercises are performed throughout the period of treatment.

In this series there was no fracture with more than a few millimetres displacement of the condylar fragment. One fracture with marked displacement, which radiologically appeared to be of this type, could not be reduced by manipulation, and open reduction was then performed. At operation a depressed fragment of articular surface was found between the main fragments, preventing reduction, and the main condylar fragment was too comminuted to allow the satisfactory insertion of a screw after reduction had been obtained. This type of fracture is a combination of Types I and II and is considered later.

FIG. 13 FIG. 14

Type II (compression) fracture. Figure 13—Before treatment. Marked displacement. Figure 14—After manipulation.

Treatment of Type II (compression) fractures—When displacement is minimal, and when a small central or medial fragment of the articular surface is depressed but most of the articular surface remains in normal alignment, the knee is immobilised in a plaster cylinder, extended and moulded into varus or valgus, and a similar programme to that outlined for split fractures without displacement is followed. When displacement is moderate or marked manipulation under general anaesthesia is required (Figs. 4, 5, 13 and 14). The patient lies on the orthopaedic table and, while traction is maintained to the limb, the knee is forced

into a varus or valgus position. In the case of fractures of the anterior articular surface, manipulation into flexion is often effective in bringing about reduction. The limb is then fixed in traction on the table, an Esmarch bandage is applied firmly to the upper tibia from below upwards, and manual compression or percussion is applied to the fracture area in an attempt to reduce the outward displacement of the fragments (Kindersley 1937). Radiographs are taken, and when a satisfactory reduction has been obtained a long leg plaster from groin to toes is applied with the knee held in the varus or valgus position. In most cases with marked displacement the position of the fragments can be substantially improved, for it is usually possible to get the greater part of the articular surface into satisfactory alignment, and occasionally anatomical reduction may be achieved. Non-weight-bearing immobilisation is maintained for six weeks until bony union has occurred, a fresh close-fitting plaster being applied after three to four weeks when the swelling has subsided. The patient then mobilises his knee without bearing weight on it for a further three or four weeks, or until the quadriceps is strong enough to control it when graduated weight bearing is commenced. Quadriceps exercises are performed throughout the period of treatment.

Treatment of Type III (T-shaped or Y-shaped) fractures—Manipulation under general anaesthesia is performed, in the manner described for Type II (compression) fractures, when the displacement is more than slight. In the occasional case in which this form of traction is not sufficient to bring about reduction, skeletal traction is applied by means of a pin through the calcaneum. In almost every case it was possible to realign satisfactorily the greater part of the articular surfaces (Figs. 8 to 12). A plaster from groin to toes is then applied. The subsequent treatment follows the same lines as that for compression fractures, except that the period of non-weight-bearing immobilisation tends to be longer (from eight to twelve weeks).

Treatment of Haemarthrosis—Some degree of haemarthrosis of the knee joint is a constant accompaniment of tibial condyle fractures. In twenty-two patients in whom the haemarthrosis was causing distension of the joint aspiration was performed in the theatre with full aseptic technique before manipulation and immobilisation.

Operative reduction—The indications for operative reduction were as follows: 1) Failure to improve substantially the position of fractures with marked displacement by closed methods. This occurs most frequently in the mixed split and compression type of injury (Figs. 15 and 16), in which reduction is impeded by the interposition of the depressed central articular fragment or the displaced semilunar cartilage, or by both. 2) Instability of the fracture after manipulative reduction.

The ten fractures treated by operative reduction were not the worst fractures in the series. The indications for operation in two of them were not clear, and the author's impression is that the results of these might have been better had they been treated by conservative methods.

Operative technique—In each case the knee was explored through an antero-lateral incision and the haemarthrosis evacuated. The semilunar cartilage was inspected and if it was intact or only slightly damaged it was retained. When it was seriously displaced or damaged it was excised. The depressed fragments of the tibial articular table were elevated and any completely detached fragments removed. Whenever possible the main fragments were fixed in position by one or two screws. In some cases the condyle was found to be too comminuted for internal fixation of this sort; pre-operative radiographs sometimes give little hint as to the presence of extensive comminution. After closure of the wound a groin to toe plaster was applied. The post-operative programme was the same as that of the cases treated conservatively.

RESULTS

Sixty patients attended for follow-up, of whom fifty had had conservative treatment and ten open reduction. Fifty-five patients were examined by me personally and the rest by orthopaedic colleagues at other clinics.

FIG. 15

FIG. 16

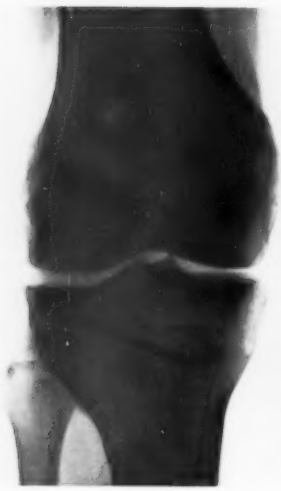

FIG. 17

Combined Type I and Type II fracture. Figure 15—Before treatment. Figure 16—After open reduction and internal fixation. Figure 17—Two years later. Osteoarthritic changes in lateral compartment.

In the assessment of results the criteria used conformed to those of Palmer (1951), namely: **Excellent**—Pain-free, full function, normal or almost normal mobility, stable, no atrophy. **Good**—Pain-free or occasional aching after activity, good mobility, moderate atrophy, increased crepitation compared with the other side, stable. **Fair**—Inconvenience limiting the working capacity, reduced mobility, atrophy, deformity, marked crepitation, slight instability. **Poor**—Rest pain, poor mobility or ankylosis, deformity, or gross instability.

These patients were all treated between 1941 and 1953, and the average length of follow-up was four and a half years. The shortest follow-up was six months and the longest twelve and a half years. Fourteen patients were followed up for over five years. Three were followed up for over eight years and six for over ten years. Ten of the fourteen patients followed for more than five years had excellent results, and all those followed for more than eight and ten years had excellent results.

The results are assessed according to the type of fracture and the method of treatment (Tables III to V).

The least satisfactory results followed the combined Types I and II fractures (which are here included in the Type II group). Forty-three per cent of such fractures (including operative cases) had excellent results, 36 per cent good and 21 per cent fair, compared with 80 per cent excellent and 20 per cent good results from the remainder of the Type II fractures.

Of the Type III (T-shaped and Y-shaped) fractures 80 per cent had excellent results. Open reduction was performed in three cases because one of the fractured condyles had a combined Type I and II fracture which could not be satisfactorily reduced by manipulation and traction.

The results of the whole series were 73·6 per cent excellent, 18·3 per cent good, 6·6 per cent fair and 1·6 per cent poor.

Fracture of the fibular neck occurred in seventeen patients, but in none was there injury to the lateral popliteal nerve. These fractures do not appear to influence the results.

In seven out of the ten patients treated by operative reduction the semilunar cartilage was found to be damaged and was excised. This suggests that quite a number of the fairly severe fractures that were treated conservatively also had associated cartilage lesions, yet no patient had clinical evidence of such an injury at the time of the follow-up examination.

This observation accords with those of other authors (Clarke 1935, Barr 1940, Palmer 1951) and suggests that in patients treated by operation the cartilage should be conserved unless grossly damaged or displaced.

A period of immobilisation in plaster followed by non-weight-bearing exercises was considered of particular importance because ligamentous injury is a common feature, and its presence was taken into account when the programme of treatment of the individual

TABLE III

LATE RESULTS OF ALL 60 CASES

Type	Number of cases	Result			
		Excellent	Good	Fair	Poor
I	7	7	—	—	—
II	38	25	10	3	—
III	15	12	1	1	1
Totals	60	44	11	4	1

TABLE IV

RESULTS OF CONSERVATIVE TREATMENT (50 CASES)

Type	Number of cases	Result			
		Excellent	Good	Fair	Poor
I	7	7	—	—	—
II	31	24	6	1	—
III	12	10	1	—	1
Totals	50	41	7	1	1

TABLE V

RESULTS OF OPEN REDUCTION (10 CASES)

Type	Number of cases	Result			
		Excellent	Good	Fair	Poor
I	—	—	—	—	—
II	7	1	4	2	—
III	3	2	—	1	—
Totals	10	3	4	3	—

fracture was decided. Although several fractures were originally associated with marked ligamentous instability, only one operative repair was performed. At follow-up there was one patient with definite ligamentous laxity and fourteen others with a trace of laxity, chiefly due to a minor residual valgus deformity, but in all these patients stability of the knee joint was well controlled by the quadriceps muscle.

In any assessment of the function of a joint the range of movement is an important consideration. In this series 70 per cent of the patients treated conservatively regained active knee flexion to 45 degrees or less, and only 8 per cent failed to gain flexion as far as 90 degrees.* Patients treated by operation did not show such good results in this respect, for only two patients out of the ten operated upon regained flexion to 45 degrees or less, and five failed to achieve active flexion to 90 degrees.

Residual atrophy of the thigh muscles of half an inch or more (measured five inches above the superior pole of the patella) was present in twelve patients, of whom four had been treated by open reduction.

Of the two pathological fractures in the series, the first was a Type III fracture of a tibia which was the site of Paget's disease. The fracture united satisfactorily and quite rapidly, and in spite of a further fracture of the upper end of the same tibia a year later, the result after eight years was excellent. The second was a Type III fracture in a patient with severe rheumatoid arthritis, who had had a pseudarthrosis performed upon the hip of the

* Full extension = 180 degrees; full flexion = 45 degrees or less.

same side two years before. The fracture was sustained while the patient was weight bearing without her caliper. Twenty months later the knee was stable, but pain persisted and movement was poor. This was the only poor result in the series.

Since three-quarters of these fractures occurred after the fourth decade of life, many patients showed radiologically some osteoarthritic change in the knee at the time of injury. So great is the variation in the normal degree of degenerative change that can be expected to be present during these later decades (Bennett *et al.* 1942) that it is difficult to assess the effect of trauma upon the progress of osteoarthritis. From a study of the radiographs of patients who sustained the injury during the third and fourth decades, the impression is gained that degenerative changes appear within eighteen months to three years; they are localised mainly to the damaged side of the joint and are not related to the severity of the injury as shown by the radiographs (Fig. 17). None of these patients had clinical evidence of such degenerative changes.

It is a striking fact that excellent function is frequently present in spite of the persistence of deformity of the tibial articular surfaces in the radiographs.

Analysis of the end-results in relation to the age of the patient at the time of injury shows that age has not had any appreciable influence upon the result; of the twelve patients aged between sixty-one and eighty years, eleven had excellent results and the twelfth a good result.

COMMENT

The aim of immediate treatment in fractures involving articular surfaces is to restore anatomical reduction. Because of the comminuted nature of most fractures of the tibial condyles it is often impossible to achieve the desired accuracy of reduction by any means. Some of the fragments of the tibial articular surface may be completely detached, and others nearly so, necessitating revascularisation of the fragments and leading to degeneration of the overlying cartilage. Complete regeneration of articular cartilage does not occur and the foundations for a degenerative arthritis are consequently already laid. In most of these fractures the position of the fragments can be considerably improved by the conservative measures already described, but perfect reduction is seldom achieved. Open reduction with internal fixation leads to greater improvement in the radiographic appearance, though in comminuted fractures anatomical reduction is not usually obtained and function is frequently disappointing. This is not altogether surprising, for dissection of soft tissues may endanger the blood supply of marginal fragments and cause periarticular fibrosis.

The analysis of the long-term results in this series suggests that conservative treatment along the lines set out gives good results, and that operative reduction should be reserved for fractures in which restoration of the general contour of the articular surface cannot be achieved by closed manipulation, or in which a satisfactory manipulative reduction cannot be maintained by external fixation alone. In the absence of either of these indications comminution should be regarded as a contra-indication to operative reduction.

SUMMARY

1. Sixty fractures of the tibial condyles have been reviewed. Fifty were treated by conservative measures and ten by operative reduction. The fractures are classified and the etiology, age incidence, mechanism of injury, methods of treatment, and results are discussed.
2. The indications for operative reduction are described.
3. The combined split and compression types of fracture give the least satisfactory results.
4. Age is no contra-indication to immobilisation in the treatment of these fractures.
5. Emphasis is laid upon the necessity for immobilisation in the treatment of the associated ligamentous injuries.
6. It is considered that the results justify the policy of treatment described.

I wish to thank Mr J. C. Scott and Mr G. P. Mitchell for the stimulus and advice they have given me in the preparation of this paper.

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TRAUMATIC ANEURYSM OF THE PERONEAL ARTERY

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The convenience of a tourniquet may be offset by post-operative complications associated with its use. Traumatic aneurysm, although uncommon, is one such complication. Elkin (1948), describing 650 traumatic aneurysms, noted only six caused by surgery. That this complication is particularly liable to occur in certain sites is illustrated in this account.

The aneurysm described here followed the use of a modified postero-lateral approach to the subtalar joint resembling that described by Gallie (1943). Dick (1953) has recently emphasised the risk of damage to the peroneal vessels in operations through this incision. Two anatomical features were noted in this case which make the peroneal artery especially liable to injury in this otherwise excellent approach.

CASE REPORT

A girl of eighteen attended with a Brodie's abscess in the lower part of the left tibia. The lesion was excised through a postero-lateral approach. Although not the most direct, this incision was used because it afforded the best soft-tissue closure.

Fig. 1
Arteriogram of peroneal artery.

At operation the peroneal vessels were not evident and no special effort was made to define them. The bone focus was excised and the wound closed in layers. The wound healed without incident.

Six weeks after operation, although the patient remained free from symptoms, it was noted that the skin temperature was raised in the neighbourhood of the incision and that the centre of the wound pulsated synchronously with the posterior tibial artery. On auscultation a harsh murmur was heard in the same region. A similar loud murmur was audible between the tibia and fibula anteriorly at the same level; it was diminished by pressure over the perforating peroneal artery. The circulation of the foot was normal and the pulse pressure was unaffected by firm pressure over the wound.

A false aneurysm of the peroneal artery involving its perforating branch was diagnosed. The patient was readmitted and the wound explored.

Operation—The scar of the previous operation was excised and the incision was extended proximally. The peroneal artery was exposed in this extension of the wound and was found in the substance of the flexor hallucis longus muscle. An arteriogram defined the site and the extent of the aneurysm and simplified the remainder of the operation (Fig. 1).

The aneurysm was dissected from the dense surrounding scar tissue. The peroneal artery entering the sac proximally was easily controlled by ligation. No sign of this artery was found distal to the aneurysm. On opening the sac blood regurgitated briskly from the perforating peroneal artery, which, passing immediately forwards through the interosseous membrane, could not be isolated. The sac itself was therefore mobilised and ligated as close as possible to the exit of this vessel. When this artery had been controlled the remainder of the sac was excised.

No sign of an arterio-venous communication was discovered, despite the rapid filling of the veins seen in the arteriogram. There was no evidence of infection.

The patient made an uneventful recovery and there was no sign of recurrence a year and a half later.

DISCUSSION

In operations with a tourniquet in place, damage to important smaller vessels must be common. Despite the relative infrequency of complications, and where vessels are known to be at a risk, damage should be avoided. In this region two anatomical features make the peroneal artery liable to injury.

First, the relationship between the peroneal vessels and the flexor hallucis longus muscle, though variable, is an intimate one. The vessels lie either deeply, anterior to the muscle, or, as in this instance, within its substance (Fig. 2). As retraction of the muscle medially is an essential part of the exposure, the vessels in either case are liable to damage if their location is not first defined.

Secondly, the perforating branch of the peroneal artery leaves it at the critical level of retraction. This tethers the vessel, resulting in damage to one or other component if retraction is unguarded. In the case described here it seems probable that the main vessel distal to the perforating branch suffered.

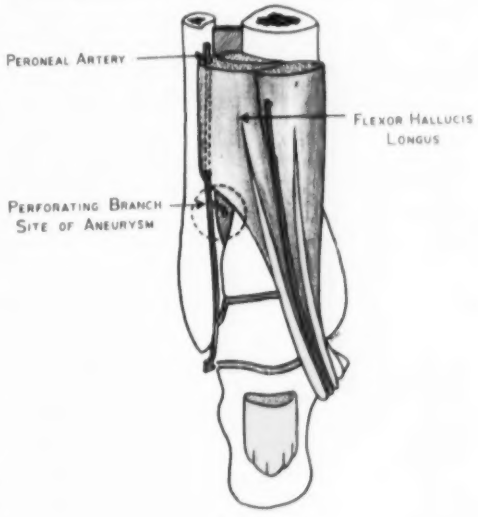

FIG. 2

Diagram showing the peroneal artery and its perforating branch with its relationship to the deep group of foot flexors and the posterior tibial artery.

Thus the manoeuvre of retracting the flexor hallucis muscle, which protects the more obvious posterior tibial vessel and nerve, may damage the smaller peroneal vessels.

As the original operation was undertaken for a bone abscess it is possible that sepsis may have been a factor in producing this aneurysm, but this is unlikely in the absence of any sign of infection at the second operation.

SUMMARY

A case of traumatic aneurysm of the peroneal artery at the level of its perforating branch is described. The intimate and variable relationship of this vessel to the flexor hallucis longus muscle and the tethering effect of its perforating branch predispose to its damage in operations through the postero-lateral approach to the region of the ankle.

I would like to thank Professor Walter Mercer and Mr I. Lawson Dick for their permission and encouragement to publish this account. I would also like to acknowledge with thanks the advice and assistance of Dr Catherine Burt, and, for performing the arteriogram, Dr A. A. Donaldson of the Department of Radiology, Royal Infirmary, Edinburgh. Finally I would like to thank Mr J. C. Scott of Oxford for his help in the preparation of this paper.

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ANEURYSM AFTER FOOT STABILISATION

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Traumatic aneurysm is a sufficiently rare complication of the surgery of the foot to warrant a record of the following three cases.

Case 1—A boy of fifteen underwent a bilateral Steindler's operation for pes cavus. Twenty-nine days later he was readmitted complaining of throbbing pain in the right foot. His plaster was bivalved and approximately 30 millilitres of fresh blood was aspirated. A crepe bandage was applied and the posterior shell retained. Two days later still the overlying skin was observed to be tense. The haematoma had increased in size; it was pulsatile, and there was a murmur present over it on auscultation. Next day the medial side of the foot was re-explored. A large false sac covered by fibro-fatty tissue was found. The clot was evacuated, a bleeding point in the muscle was ligated and the vessels were tied at both ends. The defect appeared to be a hole three millimetres across in the anterior wall of the medial plantar artery. The patient's subsequent convalescence was uneventful.

Fig. 1

Fig. 2

Case 2. Figure 1—The aneurysmal swelling. Figure 2—Low-power photomicrograph of the fibrous false wall and contained blood clot.

Case 2—A grocer's boy, aged fifteen and a half years, with peroneal muscular atrophy and consequent talipes equinovarus, had undergone Steindler's operation ten years before and medial capsulotomy of the talo-navicular joint and elongation of the tendo calcaneus eight years before. A Lambrinudi's arthrodesis of each tarsus was carried out. A week after the operation on the right foot, the plaster was changed because of residual equinus deformity, but nothing was noticed amiss and he walked in plaster three weeks later. After further change of plaster eleven weeks after operation a pulsating swelling about three-quarters of an inch in diameter was noticed on the back of the foot, evidently near the middle of the dorsalis pedis artery. Examination elicited the clinical characteristics of an arterio-venous aneurysm.

Next day the swelling was explored and excised under a general anaesthetic and with tourniquet haemostasis. Just lateral to the extensor hallucis longus tendon, and overlapped by it, there was a globular, maroon coloured, semi-solid swelling about three-quarters of an inch in diameter, with a thin, friable, rough covering. The dorsalis pedis vessels were clamped and tied distally. The swelling was then separated backwards from its surroundings and from the underlying bone and turned proximally. The bone presented a shallow round pit, about a third of an inch in diameter, from which periosteum and cortex had disappeared, leaving cancellous bone exposed. A disc comprising the eroded area and a margin of normal looking bone was removed with a gouge for histological examination. The swelling was finally freed by ligating and dividing a proximal pedicle containing the dorsalis pedis vessels. After removal of the tourniquet haemostasis was secured by clamping and ligation supplemented by swab pressure for five minutes. Rest in plaster-of-paris was provided for a further four weeks. The patient's progress, followed for three years, was without incident.

The specimen (kindly examined by Dr H. A. Sissons) consisted of an arterio-venous aneurysm with a wall of newly developed fibrous tissue and a lumen partly occupied by blood clot. The cortex of the underlying bone was eroded and there was some haemorrhage into the subjacent marrow where the bone was undergoing osteoclasis.

Case 3—A boy of eighteen underwent arthrodesis of the talo-navicular, subtalar and calcaneo-cuboid joints for stabilisation of his right foot which presented a severe talipes equinovarus, probably from poliomyelitis. The severity of the deformity caused a little difficulty in defining the medial side of the subtalar joint. At no time, however, did one have the impression that an osteotome had wandered too far. Convalescence was uneventful, and radiographs soon afterwards showed that the position was excellent. After twelve weeks the plaster was removed, and clinically and radiologically fusion was solid. Three weeks later a swelling was noticed on the medial side of the foot. The diameter of the swelling was about one and a half inches; it was soft and compressible, and exsanguination by a tourniquet caused its complete disappearance. A diagnosis of arterio-venous aneurysm of the posterior tibial artery and vein was made. At operation a large aneurysmal sac was exposed without difficulty. It was carefully dissected free from the posterior tibial nerve which appeared to be adherent to it at one point, and all four vessels were ligated and divided as close as possible to the sac. The convalescence was uneventful, and when the patient was last seen, three months after operation, the shape of the foot remained excellent and he was working as a country postman.

FIG. 3
Case 3—The aneurysm opened.

DISCUSSION

Although traumatic aneurysm is a common enough condition and much literature on the subject has accumulated, Elkin, in a personal series of 650 such operations, found that in only six of them could damage to a blood vessel during the course of an operation be incriminated. In none of these cases did the aneurysm follow an orthopaedic operation on the foot.

Only three references dealing with aneurysms of the foot after operation have been found in the literature. Higgs (1931) was the first to describe such a case, which resembled

in most respects Case 3 reported here. Coughlin (1951) described a case after a Steindler's operation, as in Case 1. Case 2, in which the dorsalis pedis vessels were involved, has no parallel that can be found.

A report of such cases shows that the use of a tourniquet does not absolve the surgeon from respecting blood vessels in this area. Case 3 illustrates the importance of a really adequate exposure of the subtalar joint when the articular surfaces are being resected. The commonest cause of failure to achieve this objective is incomplete division of the interosseous ligament, which is a bigger structure than many realise. Once this exposure is achieved, however, the exposure of the tendon of tibialis posterior should warn the operator of the immediate proximity of the neurovascular bundle and its liability to injury.

I am much indebted to Mr David Trevor and Mr H. Jackson Burrows of the Institute of Orthopaedics for permission to publish the first and second cases respectively. I am also grateful to Dr H. A. Sissons for his report and photomicrograph, for the assistance of Mr C. Davenport in collecting the literature, and, lastly but by no means least, to Dr Frank Robertshaw, whose virtuosity extended beyond his anaesthetic duties to the taking of the photograph in Case 3.

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RUPTURE OF THE COLLATERAL LIGAMENT OF THE METACARPO-PHALANGEAL JOINT OF THE THUMB

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The metacarpo-phalangeal joint of the thumb permits flexion and extension only and the range varies widely in different individuals. This is due to differences in the shape of the metacarpal head and the tension of the capsule. Joseph (1951) has shown that the metacarpal head may be flat or round and that the range of movement varies between 5 and 88 degrees. Thumbs with the smaller range tend to have flat metacarpal heads and those with the greater

Fig. 1

Fig. 2

Figure 1—The swelling can be seen in the web at the base of the thumb.

Figure 2—Photograph showing the deviation of the thumb from the index finger when the collateral ligament is ruptured.

range to have round heads. The joint is a hinge, but when the metacarpal head is rounded some gliding of the base of the phalanx will increase the range of movement. Whatever the range of flexion, movement in other planes is negligible as it is effectively prevented by the collateral ligaments. These consist of short strong bands of fibres which radiate from depressions on either side of the head of the metacarpal to the base of the first phalanx and sesamoid bones. They extend distally and a little forward so that the greater number are inserted anterior to the axis of movement. With the thumb in the extended position they give to the metacarpo-phalangeal joint the stability so important in gripping. This is particularly so in the pincers action of the thumb when the pulp is compressed against the pulp of one of the fingers, usually the index or middle finger. When the stability of the joint is weakened, as when a collateral ligament is ruptured, this action is greatly weakened. As Watson-Jones (1943) pointed out, when the ligament on the side nearest the index is deficient, pressure merely pushes the thumb away and opens the joint on the same side. The ligaments are comparable with the collateral ligaments of the knee. With the knee extended, rupture of the medial ligament produces a similar weakness and instability.

Mechanism of injury—The ligament is damaged by a blow on the thumb in the extended position. Partial rupture may occur and cause pain and swelling, but no instability, and provided the joint is protected by a plaster healing will occur with no permanent instability. If the rupture is complete the stability is destroyed and subluxation of the phalanx on the metacarpal head occurs. This is towards the radial side, as already explained, but some forward shift may also occur. If a chip of bone is avulsed the lesion will be obvious in the radiograph, but not otherwise, and the slight shift of the phalanx on the metacarpal head is easily overlooked.

FIG. 3

Marked shift of the phalanx on the metacarpal head when radiographed with abduction stress.

Clinical features—The patient complains of a swelling in the web at the base of the thumb (Fig. 1), with pain and weakness of grip. If he is asked to press the tip of the index finger against the thumb, comparison of the two hands will show a deviation of the thumb away from the index (Fig. 2). A radiograph will show the shift of the base of the phalanx on the metacarpal head, which can occur only if the ligament is ruptured. The opening of the joint when radiographed under strain is similar to that seen in the knee forced into valgus after rupture of the medial ligament (Fig. 3). In such cases stability can be restored by operative reconstruction of the ligament.

Operative repair—The joint is exposed and the periosteum of the metacarpal and phalanx is elevated. Holes are bored, taking care to preserve the small bony ridges between them. The extensor tendon of the fourth toe is removed from the base of the toe to the lower edge of the extensor retinaculum. The tendon is threaded through the holes and pulled tight to reduce the subluxation and sutured to itself (Fig. 4). Plaster fixation is maintained for four weeks to allow consolidation. Mobilisation of the thumb is quick as the increased stability returns the strength to the long muscles.

FIG. 4

The method of reconstruction, using the extensor of the fourth toe.

CASE REPORTS

Case 1—A medical student ruptured the collateral ligament at the base of the thumb in a motor cycle accident. The thumb was fixed in plaster for six weeks and he was allowed free for two months. The thumb was weak and he was unable to grip. Radiographs revealed marked displacement when strain was applied (Fig. 3). The ligament was reconstructed and the thumb fixed in plaster for four weeks. Two months later he had full function and stability.

Case 2—An apprentice coppersmith was struck on the thumb by a baseball bat. He had the characteristic swelling in the web at the base of the thumb, and radiographs revealed that there was outward shift of the base of the phalanx on the metacarpal head. A plaster was applied for

four weeks. Three weeks after the removal of the plaster the joint was unstable and he was unable to grip with the index and thumb. At operation the ligament was found completely divided and was reconstructed. Plaster fixation was maintained for four weeks. One month later he returned to work with the joint stable.

Case 3—A labourer strained his thumb severely while wrestling. He showed swelling at the base of the thumb, and the pincers action was weak. Radiographs confirmed the rupture of the ligament. The ligament was reconstructed. The thumb was stable and strong, with a full range of movement.

I am indebted to Miss D. Marshall for the clinical photographs, to Miss C. D. Entwhistle for the diagram, and to Miss L. North for secretarial assistance.

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DEPOSITION OF CALCIUM SALTS IN THE POPLITEUS TENDON

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The deposition of calcium in ligaments and tendons about the knee joint is uncommon. Lamb (1952) described two cases of deposition of calcium salts in the medial ligament, but the occurrence of deposits on the outer side of the knee does not appear to have been recorded before.

CASE REPORTS

Case 1—A male cook aged sixty-four gave a history of pain in the postero-lateral part of the left knee for two months. Examination showed a tender swelling, which disappeared on flexion, on the outer side of the joint. A cystic lateral cartilage was suspected. A radiograph showed a deposit lying in the position of the popliteus tendon (Fig. 1). As the symptoms were not relieved by rest the knee was explored. Arthrotomy revealed an intact lateral cartilage without evidence of cystic degeneration, but the popliteus tendon was found to be oedematous with a whitish mass discernible within its substance. After incision of the sheath, a semi-solid deposit which was under considerable tension was removed. Subsequent progress

Fig. 1
Case 1—Initial radiograph.

Fig. 2
Case 1—Two months later.

was uneventful and the patient returned to work a month later. A radiograph two months later (Fig. 2) showed very little evidence of the deposit.

Pathological examination—The material was chiefly acellular collagen with a low calcium content. It was not possible to estimate the relative proportions of calcium phosphate and calcium carbonate.

Case 2—A woman aged sixty had complained of severe pain on the outer side of the knee for two days. On examination the knee was found to be swollen, movements were considerably restricted and there was tenderness over the lateral joint line. A tear of the lateral cartilage was suspected. A radiograph showed a deposit of calcium on the lateral side of the joint

FIG. 3
Case 2—Initial radiograph.

FIG. 4
Case 2—Six weeks later.

(Fig. 3). With rest in bed the pain rapidly subsided, and a radiograph taken six weeks later showed the mass to be much smaller (Fig. 4). A year later the knee remained painless.

SUMMARY

1. Two cases of deposition of calcium on the outer side of the knee are described.
2. The condition is believed to be uncommon and does not appear to have been described before.
3. One case resolved with conservative treatment, the other after an operation at which the deposit was found in the tendon of popliteus.

I wish to thank Mr J. S. Batchelor for permission to use the case notes.

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ACUTE EPISODES WITH CALCIFICATION AROUND THE HIP JOINT

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Calcification in the supraspinatus tendon at the shoulder is well recognised as a cause of shoulder pain. Sudden onset of very acute pain and gross limitation of movement may follow the rupture of such a deposit, but with rest and sedation the condition clears up spontaneously with the absorption of the calcified material (Blundell Jones 1949). There have been many descriptions of calcification occurring in tendons and ligaments in the neighbourhood of other joints, including the hip joint, but the author has been unable to find any reference to acute episodes in the hip similar to those seen in the shoulder. The following seven cases are therefore reported.

CASE REPORTS

Case 1—A man of twenty-nine was suddenly seized by agonising pain in the right hip while climbing some stairs. He was unable to move further and was admitted to hospital. The hip was held in 30 degrees of flexion, abduction and lateral rotation, all movements being restricted by pain and muscle spasm. Radiographs revealed calcification just above the hip joint (Fig. 1).

Fig. 1

Fig. 2

Case 1. Figure 1—Initial radiograph. Figure 2—Four weeks later.

With rest in bed and sedatives the pain gradually subsided and full painless movement was regained in two weeks. He resumed normal duties in four weeks, and radiographs then showed absorption of the greater part of the calcified deposit (Fig. 2).

Case 2—A woman of forty-one attended first with an acutely painful shoulder due to rupture of a calcified deposit in the supraspinatus tendon (Fig. 3). This cleared up with rest in three weeks and the calcified deposit absorbed spontaneously. One year later she sought advice for pain in the right hip of sudden onset, which immobilised her. The clinical signs were not so marked as in Case 1: adduction and rotation were most limited, while flexion and abduction were painful only in the last quarter of the range. Radiographs revealed calcification above the greater trochanter (Fig. 4). Rest in bed for two weeks with progressive exercise restored full movement. After four weeks she had full function, and radiographs showed the deposit absorbed (Fig. 5).

Case 3—A woman of forty-nine was confined to bed with a " chill " for a few days and on getting up was seized with pain in the right hip, which she was then more or less unable to move for a

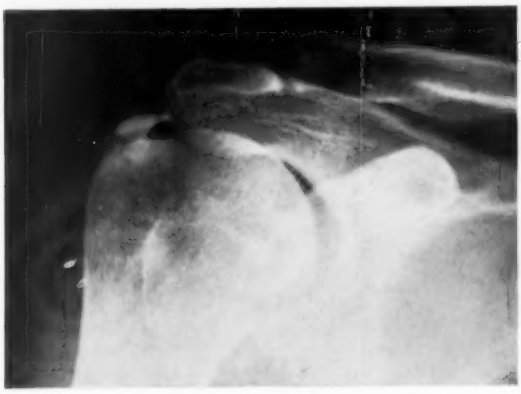

FIG. 3

Case 2—Radiograph of shoulder showing calcified deposit in the supraspinatus tendon.

FIG. 4

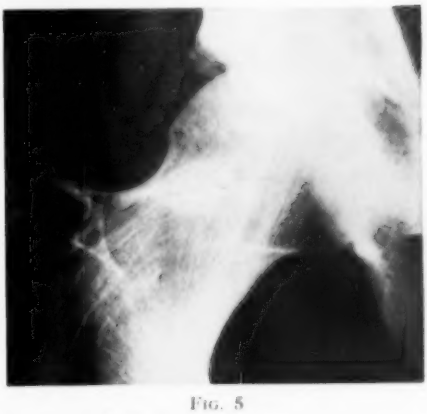

FIG. 5

Case 2. Figure 4—Initial radiograph. Figure 5—Four weeks later.

FIG. 6

FIG. 7

Case 3. Figure 6—Initial radiograph. Figure 7—Three months later.

week. When first seen she still experienced pain on walking, and abduction was a little limited though other movements were free. Radiographs showed calcification above the hip (Fig. 6). Some symptoms persisted for three months, but by the end of that time she had regained full function and radiographs showed the deposit absorbed (Fig. 7).

Case 4—A woman of forty-two developed sudden pain in the right hip, necessitating rest in bed for a few days. When she was first seen two weeks later the pain had gone and there was normal

FIG. 8

FIG. 9

Case 4. Figure 8—Two weeks after onset. Figure 9—Four weeks later.

movement in the joint. Radiographs revealed a calcified lesion similar to that seen in the previous cases (Fig. 8). One month later the deposit had been absorbed and she had full function (Fig. 9).

Case 5—A farmer aged thirty-five felt sudden severe pain in the right hip while walking, and had to retire to bed four days later. Pain was severe and required morphine for relief. The clinical

FIG. 10

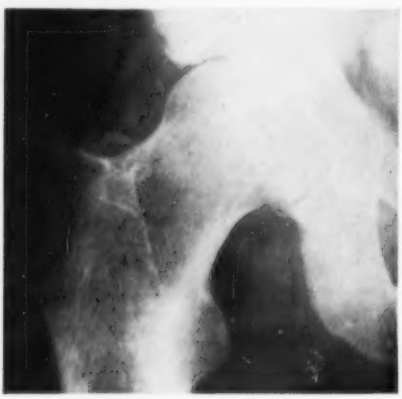

FIG. 11

Case 5. Figure 10—Initial radiograph. Figure 11—Five weeks later.

signs were like those in Case 1. Radiographs showed a calcified deposit (Fig. 10). Two weeks later he was able to do light work and five weeks later the hip was normal (Fig. 11).

Case 6—A farmer aged fifty-six developed gradually increasing pain in the left hip and limped for two months, but was able to continue at work until sudden onset of very severe pain immobilised him in bed. When first seen two weeks later he had almost full painless movement. Radiographs showed a calcified deposit well on the way to absorption (Fig. 12).

Case 7—A man of forty-five stumbled and twisted his left hip. Severe pain followed, with marked limitation of movement and muscle spasm. Radiographs revealed calcification as in previous cases (Fig. 13). In two weeks movements were practically full and one month after the onset the calcium was absorbed (Fig. 14). Function was then normal.

FIG. 12

Case 6—Small deposit, probably absorbing, seen two weeks after onset of severe pain.

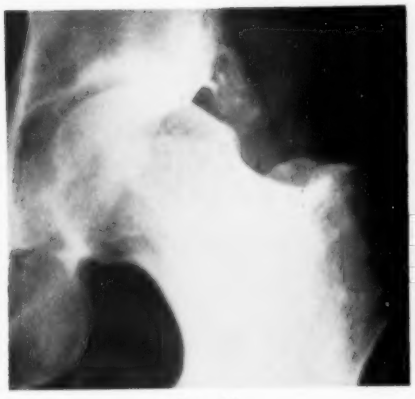

FIG. 13

FIG. 14

Case 7. Figure 13—Initial radiograph. Figure 14—Four weeks later: deposit almost absorbed.

DISCUSSION

Goldenberg and Leventhal (1936) reviewed radiographs of 550 hips in patients between the ages of fifteen and sixty-nine, and found calcified deposits near the greater trochanter in thirty (5·4 per cent). They studied twenty-five of these cases in detail and concluded that the calcification occurred in three situations: 1) In the tendon of the gluteus medius; 2) in the bursa between the tendon of gluteus medius and the greater trochanter; and 3) on the under-surface of the gluteus medius and not connected with the trochanter.

Most of these cases appear to have been of the chronic type, analogous to the painful shoulder with an unruptured deposit, and surgical removal of the deposit was recommended.

In the present series, with the exception of Case 2, in which the deposit was in the position of the gluteus medius tendon, stereoscopic radiographs suggested that the calcified material

was either on the under-surface of the gluteus medius or in the capsule of the joint. The physical signs immediately after the onset of severe pain were those of acute synovitis of the hip, movement being limited and painful in all directions, the hip being typically held in a little flexion, abduction and lateral rotation. This suggests that the deposit ruptured into the hip joint, rather than from tendon into soft tissues or into bursa. The material is extremely irritant and provokes a hyperaemic reaction with acute synovitis, which facilitates its spontaneous absorption.

It may be that this fourth type of calcification in the joint capsule is particularly liable to give rise to an acute episode because rupture into the joint occurs easily.

I am indebted to my colleagues Mr Norman Capener, Mr F. C. Durbin, and Mr Hedley Hall for three of the cases, and to Mr A. Reaney for the radiographs.

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DEPOSIT OF CALCIUM SALTS AT THE WRIST

Report of Two Cases

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The familiar site for calcium deposit in tendon is at the shoulder. Analysis of material obtained by Elmslie (1932) from the supraspinatus insertion of one patient demonstrated calcium phosphate, with small amounts of calcium carbonate and undetermined ash. Other regions where deposits have been observed are the hip, knee, foot, toes, elbow, wrist,

FIG. 1

Case 1—Note the swelling at the base of the metacarpal of the left thumb and in the anatomical snuff-box, masking the normal contours.

FIG. 2

FIG. 3

Case 1—Left wrist. Calcium deposit at the base of the thumb metacarpal (Fig. 2). Four weeks later the deposit had been absorbed (Fig. 3).

metacarpo-phalangeal region, fingers and thumb (Sandström 1938, Brumbaugh 1940, Cooper 1942, Lapidus 1943, Vasko 1946, De Palma 1947, Winchester and Mekie 1947, Oldfield 1951).

The two patients reported here showed transient deposits at the wrist, and one had previously had a deposit at the shoulder. Deposits at the wrist have been described in four

patients; the site was the insertion of the flexor carpi ulnaris in two (Lapidus 1943, Winchester and Mekie 1947), and was not described in the others (Sandström 1938). Deposits at two sites were reported in 142 patients by Sandström, either in both shoulders or in one shoulder and one hip; in five patients there were deposits at three or more situations, " the different foci appearing either simultaneously or more often separated by intervals of years."

FIG. 4

FIG. 5

Case 1—Left shoulder. The radiograph taken two years previously shows the calcium deposit (Fig. 4). The recent radiograph shows no deposit (Fig. 5).

CASE REPORTS

Case 1—A married woman aged forty-six, who worked as a cinema attendant, had suffered pain " like toothache " at the radial side of the left wrist for two weeks. There was swelling at the base of the thumb metacarpal, and in the anatomical snuff-box (Fig. 1), and tenderness was localised accurately at the insertion of abductor pollicis longus. Resisted active abduction caused pain. The radiograph showed a calcium deposit at the base of the metacarpal in the region of the abductor pollicis longus insertion (Fig. 2). A radiograph of the right wrist was normal. The blood sedimentation rate was 5 millimetres in one hour (Westergren).

FIG. 6

Case 2—Swelling at the base of the right thumb metacarpal masks the normal contour.

The patient declined to have the wrist splinted and was advised to rest the hand as much as possible. A week later she stated that the pain had subsided on the day after the previous examination, and it was observed that the swelling had diminished. A week later there was no swelling, but slight tenderness was present. Wrist movement was full. The radiograph showed that the calcium deposit was partly absorbed. Four weeks after her first attendance a further radiograph showed no deposit (Fig. 3).

Two years before, the patient had attended with pain and limitation of movement of the left shoulder. A radiograph at that time showed a calcium deposit in the region of the supraspinatus (Fig. 4). With physiotherapy the pain had gone and full shoulder movement

had returned. Recent radiographs of the left shoulder (Fig. 5), and of the right shoulder, showed no abnormality.

Case 2—A woman of twenty-four, a medical photographer, burnt her right palm on a flash-bulb. Five days later she awoke with pain, like toothache, at the base of the right thumb. During the day swelling developed. Next morning the patient was awakened in the early hours by severe pain. At mid-day there was diffuse swelling (Fig. 6) and great tenderness on the dorsum over the first metacarpal base. Thumb movement was very painful, especially active resisted abduction. There were clean blister-burns on the palm, index and minimus.

FIG. 7

FIG. 8

FIG. 9

Case 2—Calcium deposit at the base of the thumb metacarpal (Fig. 7). One week later, the deposit is less clearly outlined, slightly larger and undergoing absorption (Fig. 8). Three weeks after the onset, no deposit is seen (Fig. 9).

The radiograph showed a well defined calcium deposit at the base of the right thumb metacarpal, in the region of the abductor pollicis longus insertion (Fig. 7). A radiograph of the left wrist was normal.

Because of the severe pain, operative removal of the deposit was advised, but was refused for reasons other than medical. The hand was strapped. Four days later pain and swelling were much less. Three days after this there was still tenderness, but the swelling had almost gone, and pain occurred only on movement. The radiograph then showed the deposit less clearly outlined, slightly larger, and undergoing absorption (Fig. 8). Three weeks after the onset full function was almost restored and the radiograph showed no deposit (Fig. 9).

I wish to thank Mr H. Jackson Burrows for permission to report these cases.

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BRUCELLAR SPONDYLITIS

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Bruce (1887), who discovered the responsible micro-organism in the spleens in fatal cases of undulant fever, mentioned rheumatic pains and joint swellings. Kulowski and Vinke (1932) were the first to describe spondylitis as a complication. Palagi (1934), Benassi (1952), and Janbon, Bertrand and Salvaing (1950) have reported many cases in Southern Europe; and Bishop (1939), Spink (1948), and Phalen, Prickman and Krusen (1942) reported cases in America. In Great Britain Dalrymple-Champneys (1950) mentioned one case of spondylitis among 983 cases of undulant fever. Gardner, Girdlestone and Gillespie (1932) reported a costo-sternal abscess due to brucella melitensis, but bony complications appear to be rare in this country.

Brucella melitensis occurring in goats, brucella abortus in cattle, and brucella suis in swine may all infect sheep, horses, dogs, cats and man. In this country brucella abortus is mainly responsible for the human cases.

Feldman and Olson (1933) studied the pathology of spondylitis in swine and Lowbeer (1947) produced experimental periostitis in guinea pigs as well as studying spondylitis in swine. They found mononuclear cell infiltration and abscesses involving vertebral bodies and epiphyses. The abscesses had tough fibrous capsules. Occasionally sequestra were formed, but early and extensive formation of new bone was invariable. The abscesses extended to the dura but did not penetrate it. They rarely occurred in surrounding muscles.

Symptoms in man include recent fever, pain which is often severe, and rigidity of the spine; deformity and abscesses are rare. The course is more rapid than in tuberculosis. The temperature is intermittently elevated. The sedimentation rate may be high, but is variable. Radiographs show early and extensive bone proliferation, absence of rarefaction, early sclerosis of bodies, and narrowing of intervertebral discs. Often there is bony fusion of vertebrae.

Diagnosis is confirmed by agglutination in dilution of one in a hundred or more, and sometimes by positive blood culture. Dalrymple-Champneys pointed out that agglutination may take up to one year to become positive, or may remain negative when the blood culture is positive. Negative agglutination zones occur.

A falling titre of agglutination is a better guide to progress than the erythrocyte sedimentation rate.

The clinical signs and radiological appearance may simulate those of tuberculosis. If there is no previous history of brucellosis and the Mantoux reaction is positive, misdiagnosis is likely, unless agglutinations for brucella are done in all doubtful cases.

Paraplegia is rare, although there were early neurological signs in the cervical cases reported by Janbon, and there was early paraplegia in the case of cervical spondylitis reported here.

In a series with few bony complications Braude, Hall and Spink (1949) obtained good results with streptomycin and sulphadiazine, but later had better results with aureomycin. Good results with aureomycin were also obtained by Stoffel (1950) and by Lindeck (1950). Harris (1950) and Ralston and Payne (1950) had success with chloramphenicol as well as with aureomycin. Heilman (1949) showed that streptomycin combined with aureomycin was most effective in mice. Herrell and Barber (1949) confirmed this in man, and found that terramycin combined with streptomycin was equally effective. Once bony complications are established, however, the efficacy of antibiotic therapy is less certain. In spondylitis, Benassi (1952)

recommended radiotherapy and short-wave diathermy in addition to antibiotics. Phalen *et al.* (1942) induced hyperpyrexia, and Kulowski and Vinke (1932) drained an abscess.

Ambulatory splinting may suffice, but treatment in recumbency is usually advisable. When spontaneous fusion appears unlikely, operative fusion may hasten return to full activity.

CASE REPORTS

Case 1—A married woman, aged sixty, was admitted to the Queen Elizabeth Hospital under Professor P. C. Cloake, complaining of pain in the neck and shoulders for sixteen months. She had noticed weakness of arms and legs for four weeks. She remembered some fever for a few days at the onset of pain. She had been treated by an osteopath with heat and manipulations. The evening temperature was 99 degrees Fahrenheit. Neck flexion was limited and there was tenderness posteriorly over the lower cervical spines. There were

FIG. 1
Case 1—Radiograph at time of admission.

FIG. 2
Case 1—Condition seven months later.

wasting and weakness of the intrinsic muscles of both hands and the flexors of the right forearm, and marked weakness of both lower extremities. Appreciation of pinprick was impaired on the right side from the eighth thoracic segment downwards. Vibration sense was lost in the left leg and coordination was poor in both legs. The brachioradialis, biceps, knee and ankle reflexes were exaggerated, and the plantar reflex was extensor on both sides. The abdominal reflexes were absent.

Investigations—Lumbar puncture showed no evidence of spinal block. The cerebro-spinal fluid showed protein 230 milligrams per cent and 40 cells per cubic millimetre, 99 per cent mononuclear. The Wassermann reaction was negative in the cerebro-spinal fluid and blood. The white cell count was 6,900 per cubic millimetre, with 66 per cent polymorphonuclears, and 30 per cent lymphocytes. Agglutination tests were negative for typhoid and paratyphoid organisms. Brucella abortus agglutinated at a dilution of 1 in 320. The erythrocyte sedimentation rate was 1 millimetre in one hour. *Radiographs*—Figure 1 shows a lesion involving the fifth, sixth and seventh cervical vertebrae; swallowed barium showed the proximal part of the oesophagus displaced forwards by an abscess anterior to the lesion.

Treatment—The patient was transferred to the Royal Orthopaedic Hospital and was treated by fixation on a spinal frame with a low head piece. Aureomycin (28 g.) combined with

streptomycin was given, and she became apyrexial in a few days. Six weeks after admission there was no neurological abnormality except slight exaggeration of the leg reflexes. Radiographs showed no further change. She was allowed up wearing a plaster collar, and she was discharged home ten weeks after admission. Three months later she discarded the collar, and seven months after admission radiographs showed no sign of activity (Fig. 2). She remains free from symptoms and has a good range of movement in the neck.

Case 2—A herdsman aged thirty-two was seen in the orthopaedic department ten weeks after he had collapsed with severe pain in the lower thoracic spine and upper abdomen. He had pyrexia, and a diagnosis of undulant fever had been made. Six months before the onset

FIG. 3

FIG. 4

Case 2. Figure 3—Radiograph soon after admission. Figure 4—Condition seven months after admission.

he had helped a veterinary surgeon to clean a cow that had just aborted. He had continued to milk this cow afterwards, and had also milked a cow that aborted later. Radiographs were normal. He was unwilling to enter hospital and was treated with chloramphenicol (21 g.) as an out-patient. Radiography twelve weeks later showed narrowing of the disc space between T.11–12 (Fig. 3). Three months after this he had a further recurrence of fever accompanied by mild jaundice. He continued to have pain in the lower thoracic spine, and he agreed to enter the Royal Orthopaedic Hospital. He had intermittent pyrexia rising to peaks of 100·8 degrees Fahrenheit, limitation of movement and tenderness over the lower thoracic spine.

Investigations—The erythrocyte sedimentation rate was 8 millimetres in one hour. The Mantoux test 1/100 was negative. Agglutination tests for typhoid and paratyphoid were negative; agglutination of brucella abortus was positive at 1 in 1,250 dilution.

Treatment and progress—The patient was treated by recumbency in a plaster bed. Three months after admission he continued to have occasional pyrexia, and the erythrocyte sedimentation rate was 50 millimetres in one hour. Agglutination of brucella abortus was positive at 1 in 500 dilution. He had upper abdominal pain intermittently which was suggestive of cholecystitis, but a cholecystogram was normal. Seven months after admission radiographs showed quiescence of the lesion (Fig. 4). The sedimentation rate was 12 millimetres in one

hour. Agglutination was negative for brucella abortus. A spinal fusion operation was performed between T.11–12, a course of aureomycin (21 g.) being given during the operation period. Fourteen months after admission he had no symptoms, and had returned to full work as a herdsman, leaving off his back support.

FIG. 5
Case 3—Early radiograph.

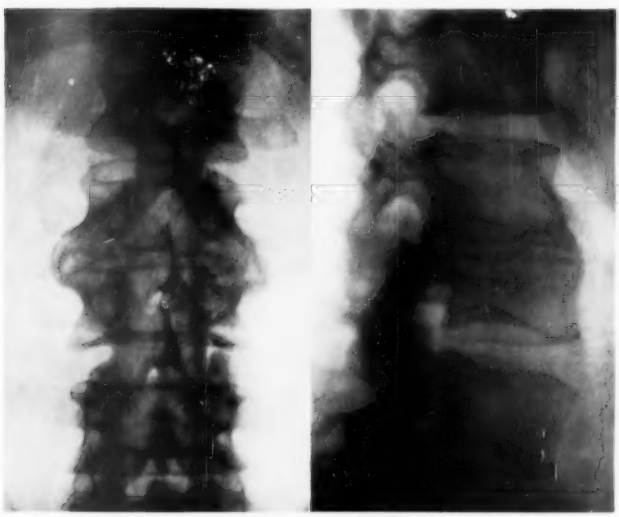

FIG. 6
Case 3—Condition five years after onset.

Case 3 (Mr Norman Roberts's case)—This patient had Malta fever in January 1946. The diagnosis was investigated and confirmed by the Department of Tropical Medicine, Liverpool. He began to have pain in his back in July 1946, the onset being sudden and the pain severe, radiating from the middle of the back to both groins. Radiographs showed spondylitis

FIG. 7. Case 4

involving L.2 and L.3 (Fig. 5). He was treated in a plaster jacket and later in a posterior spinal support. Five years later radiographs showed bony fusion (Fig. 6). The patient was well and free from symptoms. **Case 4** (Dr James Murray's and Mr H. Jackson Burrows's case)—A retired army officer, aged seventy, suffered malaise and fever (102 degrees Fahrenheit), with severe headache and girdle pain in the tenth thoracic segment. Agglutination of brucella abortus was 1 in 40 and, two weeks later, 1 in 160. There was no improvement with sulphamezathine given for twelve days, but the fever settled in four days with chloromycetin ($\frac{1}{2}$ g. six-hourly). Examination four months later revealed a lower thoracic angular kyphosis, with poor thoracic and negligible lumbar movement. There was no neurological disturbance. Radiographs showed fusion of the ninth and tenth thoracic vertebrae (Fig. 7). The pain improved, but was not wholly relieved, with a plaster-of-Paris corset, later replaced by a Fisher jacket. He still had some pain nine months later, but was able to discard the support sixteen months after the onset of symptoms. **Case 5** (Mr L. W. Plewes's case)—A retired master mariner, aged sixty-one, attended the Luton and Dunstable Hospital with backache, headache and fever of two weeks' duration. He remained pyrexial in spite of penicillin and quinine. Blood culture was sterile; brucella abortus agglutinated at 1 in 500 and brucella melitensis at 1 in 250. The white cell count was 4,500 per cubic millimetre with 34 per cent lymphoctyes. The fever subsided in a few days with a course of aureomycin, but he continued to complain of backache. Four months later he had fever again, with severe backache and lumbar stiffness. A further course of streptomycin combined with aureomycin was given.

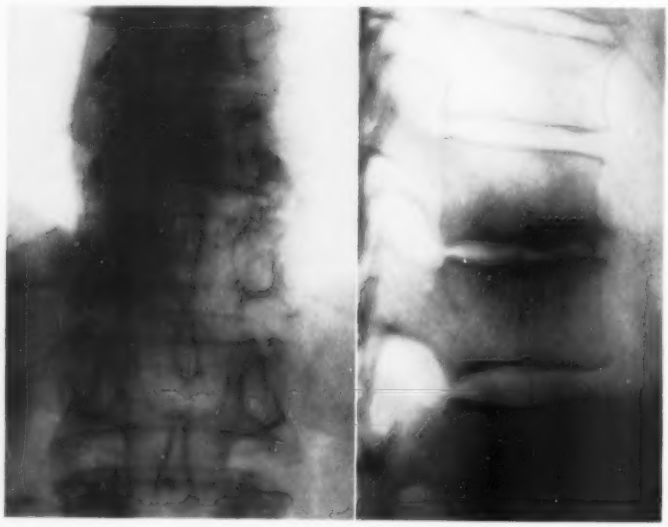

FIG. 8. Case 5

Six months after the initial symptoms he was seen by Mr Plewes, who found spondylitis with destruction between the eleventh and twelfth thoracic vertebrae (Fig. 8). He was admitted and treated with streptomycin combined with sulphadiazine, and later with streptomycin and terramycin. After a month in hospital he was discharged wearing a spinal support, and has progressed satisfactorily since.

I am indebted to Mr F. G. Allan, Professor P. C. Cloake, Mr T. S. Donovan, Mr Norman Roberts, Dr James Murray, Mr H. Jackson Burrows and Mr L. W. Plewes for permission to report their cases.

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BENIGN CHONDROBLASTOMA OF BONE

Report of a Case

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Benign chondroblastoma occurs most commonly in the second decade, usually in boys. The upper end of the humerus, in the region of the epiphysis, is a favourite site. It is interesting for the following reasons: 1) it may be mistaken for a giant-cell tumour or sarcoma; 2) it is amenable to local surgery by curettage or excision; and 3) it has a uniformly good prognosis and seldom, if ever, becomes malignant.

The complaint is usually of pain or swelling. For this reason sarcoma is often suspected at first. Histologically, the tumour is composed of polyhedral cells, with a small amount of interstitial cell substance. The sections show focal areas of calcification, and where cells and ground substance have become encrusted with calcium the tissue is necrotic. In some areas there may be direct metaplasia into bone.

The tumour was first described by Codman in 1931 as "epiphysial chondromatous giant-cell tumour of the upper end of the humerus." Codman believed that the peculiar structure of the upper end of the humerus modified the picture of a giant-cell tumour so that it did not often occur in typical form. The nature of the tumour was not clearly established until Jaffe and Lichtenstein reported several cases in 1942, with a follow-up of up to twelve years. They called the tumour benign chondroblastoma. They found that it was not confined to the head of the humerus but occurred at other sites such as the tibia, femur or ilium. Both Codman and Jaffe were of the opinion that the tumour was epiphysial in origin.

Diagnosis—Provided clinical data are combined with histological findings, the diagnosis should not be difficult, but giant-cell tumour and sarcoma, including Ewing's sarcoma, must be borne in mind.

CASE REPORT

The patient was a boy aged fourteen years. He complained of "giving way" of the left arm on lifting heavy weights, and of aching pain in the left shoulder, sufficient to keep him awake at night. These symptoms had been noticed for a year. On examination, his general condition was good. There was some wasting around the left shoulder, and there was a localised point of tenderness three inches below and behind the acromion. Muscle power was weak but the range of shoulder movements was full. There was no evidence of a neurological disturbance. *Radiographs* showed an oval translucency in the medial part of the humeral epiphysis involving the metaphysis, with some distortion of the bone outline (Fig. 1).

Findings at operation—Under general anaesthesia the head of the humerus was approached from the front. There was some difficulty in defining the muscle planes because of periarticular fibrosis. Inspection of the head of the humerus showed a roughened area of abnormal bone extending from below the medial articular margin and involving about a quarter of the articular surface. The tumour was soft and pale grey in colour. There was no cystic space. The area was curetted down to firm bone. The cavity was left.

Histological examination—The microscopic appearances were characteristic of chondroblastoma (Fig. 3). In one of the photomicrographs typical calcified areas were seen.

Progress—The patient was treated in a collar-and-cuff sling. Early movement was encouraged. When the patient was re-examined two years after the operation he was free from symptoms and had a full range of shoulder movement under good muscle control.

FIG. 1
Radiograph before operation.

FIG. 2
Condition two years after curettage.

DISCUSSION

The methods that have been used in the treatment of chondroblastoma of bone include irradiation, curettage, and local excision of the tumour with marginal bone. I believe that surgery is the treatment of choice and that x-ray therapy should probably never be used. Most authors who have described this condition have favoured surgery.

With regard to x-ray therapy, the remarks of Cade (1949) on the treatment of giant-cell tumour of bone have an important bearing on the treatment of chondroblastoma: " In the search for truth certain fundamental principles become clear . . . Tumours in children should seldom be irradiated because the treatment may cause epiphysial injury and deformity. Case reports in the literature with a follow-up of not more than three to five years cannot be relied

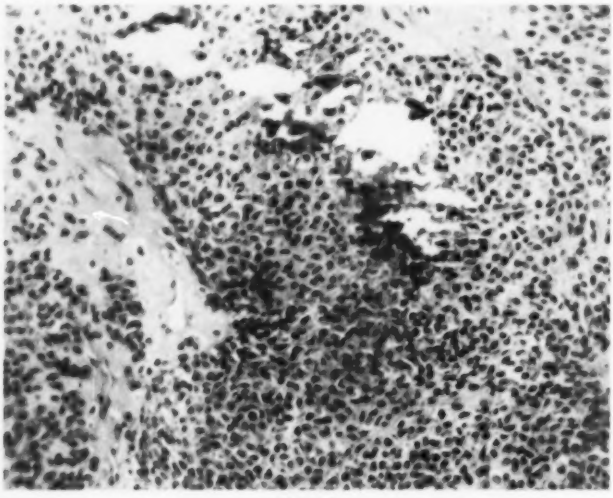

FIG. 3

Photomicrograph from a section of the tumour. (× 170.)

upon. The long-term effects of irradiation in children, with irreversible damage that may be disastrous, cannot be judged in less than ten to fifteen years." He also stated that bone sarcoma could be induced by irradiation and quoted eleven cases in which a benign tumour treated by irradiation, with or without surgical intervention, became malignant. Many cases of osteogenic sarcoma have developed in irradiated bone up to twenty-two years after the initial exposure although in many cases the dosage was greater than the 2,000 Roentgen now in use.

In view of the risks of irradiation and the unanimous report of many observers that surgery is effective in this tumour I believe that the case against radiotherapy is proved.

Incidence of the tumour—Benign chondroblastoma may be more common than is now believed. For instance, it is notable that of twenty-five cases of giant-cell tumour described by Prossor (1949) six occurred in patients under the age of seventeen years. In three instances biopsy was performed and in each a diagnosis of benign giant-cell tumour was made. In the remaining three cases biopsy does not appear to have been done; in all three the tumour was in the upper end of the humerus, but it was not recorded whether the tumours were primarily metaphysial or epiphysial. Treatment in these cases was by x-ray therapy of a dosage within or about the limit of 2,000 Roentgen. The reported results were satisfactory. It is reasonable to suppose that had these tumours been submitted to biopsy, one or more might have been a chondroblastoma.

The importance of biopsy—I submit that biopsy should be performed in every case. Without biopsy the diagnosis must always be speculative, and biopsy is essential for scientific classification of the tumours in a Bone Registry, if available. There is no evidence that biopsy has done harm and, moreover, excision biopsy may combine therapy and diagnosis effectively.

SUMMARY

A case of benign chondroblastoma in the upper end of the humerus is described. A plea is made that radiotherapy should be avoided in the treatment of this tumour. It is suggested that biopsy should be performed in every case.

My thanks are due to Mr Dillwyn Evans for permission to publish this case and for advice, and to Mr E. Mervyn Evans, Professor J. Gough, and Dr Roger Seal. I am grateful also to Dr H. L. Jaffe, who kindly examined the microscopic sections, and to Mr W. T. Gower for the x-ray photographs.

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KYPHOSIS AND FRACTURE OF THE MANUBRIUM IN TETANUS

Report of a Case

D. H. H. Robertson, Dar-es-Salaam, Tanganyika

An African boy, aged thirteen, complained that he had been unable to open his mouth since the morning. No history of preceding injury was given, though later he stated that he had had a "boil" on his buttock about a month previously. On admission he was given intramuscularly 6,000 units of anti-tetanus serum, and 500,000 units of crystalline penicillin.

Fig. 1

Fig. 2

Figure 1—Photograph seven weeks after onset of tetanus. Figure 2—Radiograph showing wedging of thoracic vertebral bodies and fracture of manubrium.

On examination the next day he was found to have marked trismus, a rigid abdomen and tonic rigidity of the lower limbs. The upper limbs, apart from the pectoral muscles, were unaffected, but the lower limbs were rigidly fixed in extension, both feet being strongly plantar-flexed. The thorax appeared barrel-shaped and the sternomastoids were in tonic spasm. The lumbar curve of the spine was exaggerated and there was an increase in the antero-posterior diameter of the chest.

No further anti-tetanus serum was given, but penicillin was administered for two weeks. Intramuscular paraldehyde and, later, Myanesin were given orally, but with little effect on the paroxysms.

Painful exacerbations of the spasm occurred with distressing frequency, the slightest stimulus producing a spasm, especially during the day. The spasms were extensor, though it was noted that during the paroxysm the sternomastoids contracted strongly and the head

appeared to be drawn down vertically towards the thoracic inlet. The paroxysms continued for twenty-four days.

A few days after his admission the boy was noted to have a pronounced depression above the sternal angle. The respiratory excursion of the chest was markedly diminished and diffuse rhonchi were audible. Cough was troublesome and only diminished as the paroxysms of spasm became less frequent.

On the fortieth day of the illness there was still some rigidity of the abdomen and legs. The muscles of the right calf were especially spastic, preventing dorsiflexion of the foot. A marked kyphosis and loss of height were noticeable (Fig. 1). Radiographs showed marked kyphosis, wedging and flattening of the bodies of the fourth to eighth thoracic vertebrae, and a depressed fracture of the manubrium (Fig. 2).

COMMENT

Fracture of the spine is a recognised complication of tetanus (Quinlan 1954). In this case there were several unusual features. The tonic spasm of the muscles of the neck, trunk, abdomen and lower limbs remained intense for a long time, even remaining in the calf muscles of the right leg forty-seven days after the onset. In addition the occurrence of the paroxysms for twenty-four days is unusually prolonged.

When the acute exacerbations of the spasm occurred it was noted that there was little head-retraction. The spasms appeared to cause vertical compression of the spine, the head being drawn down towards the thoracic inlet. It appears likely that the compression fractures of the vertebrae were caused as much by the powerful, continued, tonic spasm as by the paroxysmal exacerbations. The latter caused very little actual movement of the trunk, the muscles being almost fully contracted in their tonic state. The fracture of the manubrium was undoubtedly caused by the acute flexion of the thoracic spine.

The low dosage of tetanus antitoxin given in this case is open to criticism as it falls short of that generally accepted (Diaz-Rivera *et al.* 1951). The effectiveness of this serum in established tetanus is open to doubt and is certainly not commensurate with the cost, an important factor in tropical practice. During the last two and a half years eleven patients between the ages of five and fifteen have been treated with a single dose of tetanus antitoxin, and of these only two have died. These cases received a dose of antitoxin not exceeding 20,000 units, and in some cases only 10,000 units, as well as penicillin and sedatives. In five of these cases the possible portal of entry was that caused by the gravid female *tunga penetrans*; in others there were small septic abrasions of the feet, whereas in the rest the site was not discovered. Although these few cases could hardly be advanced as an argument against using large doses of serum, they do suggest that the prognosis at this age is quite good when small doses of antitoxin are combined with penicillin and sedation.

I am indebted to Mr J. F. S. Mitchell-Hedges of the Public Relations Department, Tanganyika, for his kindness in taking the clinical photographs and preparing the negative prints of the original radiograph. I also wish to thank the Director of Medical Services, Tanganyika, for permission to publish this paper.

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CHOPART'S AMPUTATION

The Advantages of a Modified Prosthesis

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Chopart's amputation has for many years been condemned as an unsatisfactory procedure, doomed to failure because of the alleged inevitability of plantar-flexion contracture with the development of painful callosities on the antero-inferior aspect of the calcaneum. To my surprise, however, I found in 1948 that one of the limb makers at the Artificial Limb Factory in Auckland, who was then twenty-seven years of age, had had a Chopart's amputation performed upon his left foot at the age of seven. He was wearing a blocked leather socket inside a clumsy surgical boot, and he was getting more and more pain because of increasing plantar-flexion at the ankle. He himself knew of the supposedly inevitable re-amputation in

FIG. 1

FIG. 2

Figure 1—The stump, twenty-six years old, in full dorsiflexion. Figure 2—Radiograph of the stump in full dorsiflexion and full plantar-flexion.

store for him. His foot at that time was held moderately plantar-flexed and could not be dorsiflexed as far as a right angle. He experimented with plastic sockets and endeavoured to make a new type of artificial foot. He found that the plastic socket let heat out better and was lighter and less bulky, but he also found something much more important. By moulding the plastic socket so that the back of the prosthesis was slightly narrower round its upper edge posteriorly than it was at its base, it was possible to get sufficient grip on the back of the calcaneum to hold it downwards and so modify the action of the calcaneal tendon. The plastic socket was inserted into an ordinary artificial foot so that it became part of it, and a leather ankle corset was attached. This allowed the patient to wear a pair of ordinary ready-made shoes. By 1950 dorsiflexion was well performed by the tibialis anterior, which had previously been inserted into or had gained attachment to the front of his talus, and it was obvious that re-amputation would not be required. Experiments were made with willow sockets as well as with plastic, but eventually it was found that the best socket of all was one made of stainless steel. It was much less bulky, it was cooler, it was hygienic, and it lasted.

Figure 1 shows the stump as it is now, twenty-six years after amputation, held in full dorsiflexion, and Figure 2 shows radiographs of it. The prosthesis (Fig. 3) is put on by inserting the bare stump heel first into the socket in order to get the wider lower part of the heel in

FIG. 3

FIG. 4

Figure 3—The prosthesis, showing the gentle incurving of the upper rim posteriorly. Figure 4—The prosthesis fitted to the stump and the patient standing on tip-toe with the other foot off the floor.

FIG. 5

Patient fully dressed with sock and ready-made shoe.

under the slightly overhanging sides. The fore part of the stump then fits snugly into the front of the socket and the ankle leather is laced up (Fig. 4). A sock is drawn over the artificial foot and over the ankle corset and the shoe put on (Fig. 5).

So good is this patient's control of the artificial foot that he can stand on tip-toe in it with his other foot off the floor, as shown in Figure 4, and he has an apparently normal gait.

In the last four years five other patients have been fitted with this prosthesis. Two have true Chopart's amputations. In one the stump was hopelessly fixed in plantar-flexion when first seen and will soon have to be re-amputated, but he feels that by wearing the appliance he can continue as he is for a time. The other is a Maori boy of seventeen years with multiple congenital deformities of hands and legs in whom the right leg had been amputated below the knee and the left foot amputated after the manner of Chopart. The remaining three patients had trans-tarsal amputations.

Construction of the prosthesis—The prosthesis is made by taking a plaster negative of the foot when weight bearing and making a cast-iron positive. On this the stainless steel is beaten to fit it and all of the seams except one are welded together. It then grips the contours of the concavo-convex surfaces of the iron cast, but can be removed from it in two pieces. These two pieces are then welded together and the whole is fitted and bolted into a standard willow footpiece. A leather ankle corset is attached, and a pick-up of elastic webbing can be added if desired.

One of its good features is that it can be worn inside a ready-made shoe. It makes the stump more or less part of the artificial foot and gives fairly normal control of it. The old surgical boot with a cork block in the toe never did this. It allows perspiration to evaporate freely, and is easily kept clean and bright.

Comment—This modified prosthesis has aroused my interest in the possibilities of reclaiming the Chopart amputation from the disrepute into which it has fallen. The opportunities for practising it must be rare, rarer even than for a Syme's amputation. Nevertheless here is a man who still walks on the plantar surface of his calcaneum, has a full normal range of dorsiflexion at the ankle, wears ready-made shop shoes, and can raise the heel of the affected side with the other foot off the ground. And the amputation was twenty-six years ago. It is probably necessary, for such success, to attach the tibialis anterior—and in fact all of the available dorsiflexor muscles—firmly to the front of the talus, and it seems necessary also to use a prosthesis such as this with its restraining action on plantar-flexion of the stump.

After all, if it were tried and were to fail, it would still be possible to substitute for it a Syme's amputation in the case of a man or a below-knee amputation in the case of a woman.

MELORHEOSTOSIS OF THE UPPER LIMB

Report of a Case

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Melorheostosis is an unusual type of bone petrosis which typically affects the bones, or parts of bones, of one limb. The name was given to the condition by Léri and Joanny (1922), who recorded the first case. Fairbank (1951) considered that, although over forty cases had been recorded in world literature, only four authentic cases had been presented in the United Kingdom. These were the cases of Wakeley (1931), in which both lower limbs were affected; of Boggon (1938), in which the right lower limb was involved; of Franklin and Matheson (1942), in which an extensive petrosis occurred in the skull, spine, pelvis, and the bones of the arm and leg, all on the right side; and of Le Vay (1946), in which the site of the condition was the left lower limb. Three further cases have since been recorded in the British literature. The case of Thompson, Allen, Andrews, and Gillwald (1951) involved the right lower limb, that of Trevethick (1953) the left lower limb, and that of Elkeles (1954) all four limbs. Of these seven patients only two, those of Franklin and Matheson and of Elkeles, displayed an upper limb involvement. The following case of melorheostosis in the right arm and shoulder girdle was considered worthy of record because of the site and rarity of the condition.

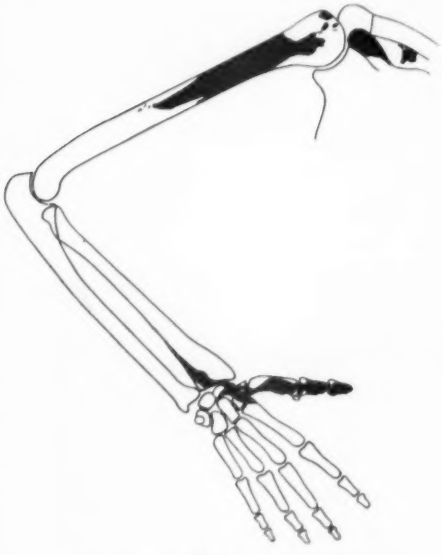

Fig. 1

Diagram of the affected areas in the right upper limb.

CASE REPORT

A coal-miner aged twenty-six years complained of pain and stiffness in the right thumb for one year. He admitted to transient pain and stiffness in the right shoulder for eight years. He had no other complaints.

Examination revealed a thickened right thumb with marked limitation of movement of the metacarpo-phalangeal joint and slight limitation of the interphalangeal joint. There were no other notable abnormalities of the limb.

Radiographic investigation demonstrated the typical "candle grease flow" of melorheostosis. The whole skeleton was radiographed and the petrosis was found to affect only the right upper limb (Fig. 1). The density was evident in the coracoid process of the scapula, the upper half of the humerus, the lower end of the radius, the carpus on the radial side, and all the bones of the thumb. Bone formation was present in the soft tissues adjacent to the clavicle. The bony outlines of the phalanges of the thumb were irregular and the radius was thickened and slightly distorted (Figs. 2 to 4).

After one year a slight but appreciable increase in the petrosis was noted in the coracoid process of the scapula and the phalanges of the thumb. This evidence supports Léri and Joanny's findings of progression in their original case of affection of the upper limb.

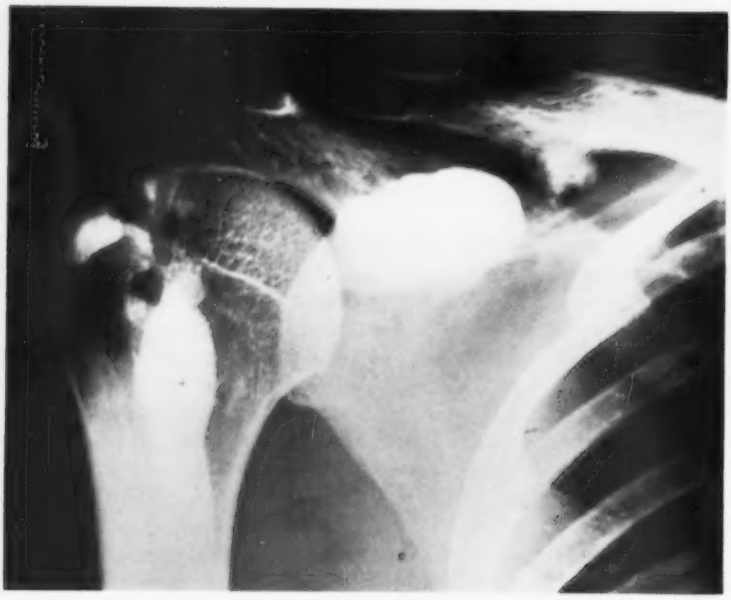

FIG. 2

Radiograph of the shoulder showing new bone formation in the region of the clavicle and the petrosis in the coracoid process and the humerus.

FIG. 3

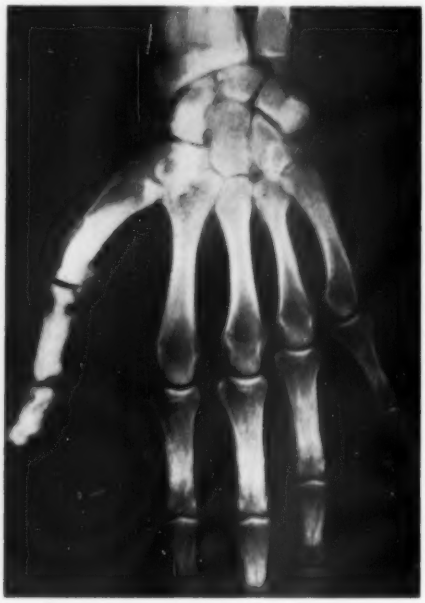

FIG. 4

Figure 3—Radiograph of the forearm and hand showing the " flow " of the petrosis and the thickening of the radius. Figure 4—Radiograph of the hand showing the degree of involvement of the thumb and the distortion of the phalanges.

COMMENT

The features distinguishing melorheostosis from generalised osteopetrosis were described by Fairbank (1951): " 1) The changes, in typical cases, are confined to the bones of one limb; 2) the outline of the affected bone is, sooner or later, distorted; 3) there is often pain, occasionally severe, sometimes unbearable; 4) there is limitation of movement in the joints formed by the affected bones." The present case displays these features and also illustrates the way the petrosis may skip a joint, here the elbow; the formation of bone in the soft tissues, seen in the region of the clavicle; and the thickening and irregularity of a bone not markedly sclerosed. This last finding in the radius is comparable to the fibular thickening in the case of Le Vay, who suggested that it might be a pre-sclerotic effect.

I wish to thank Dr J. A. MacLeod and his staff for the radiographs.

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CRITICAL REVIEW

METHODS OF MEASUREMENT OF MUSCLE AND JOINT FUNCTION

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" In the movements of an extremity, the two most important factors involved are the power or amount of force present and the amplitude or range of motion; the former being indicative of the amount of function present in the muscles crossing the joint and the latter of the amount of motion between the joint surfaces " (Robinson 1921). It is perhaps necessary to add a third equally important factor, the coordination of muscular contraction required to bring about the desired movement, for without this the limbs are unable to serve a useful function. This review is specifically concerned with the two criteria of joint function mentioned by Robinson, although accurate measurements of muscle strength and amplitude of movement with the voluntary participation of the subject demand normal coordination of the muscle activity.

THE NEED FOR ACCURATE METHODS

Study in this field of medicine received its main impetus from the large number of orthopaedic cases resulting from the 1914–18 war (Nutter 1919, Albee and Gilliland 1920, Clark 1920, Rosén 1922, Silver 1923) and from the poliomyelitis epidemics in the United States at the beginning of the century (Lovett 1916). Investigations carried out at this time indicated the need for accurate assessment of muscle and joint function and led to the development of numerous instruments and methods for measuring and recording the required values. Work was carried on spasmodically until the second world war, when interest in such measurements was renewed because of the increased incidence of limb injuries. Also, with the prevalence of poliomyelitis during the last ten years, further studies have been undertaken in connection with the problems of rehabilitation after this disease.

The practical application of the accurate knowledge of the force and amplitude of movements is apparent in many branches of medicine (Martin and Lovett 1915, Albee and Gilliland 1920, Rosén 1922, Wiechec and Krusen 1939, Molander and Weinmann 1942, Schwab, Watkins and Brazier 1943, Taylor and Brozek 1944, McIntosh, Badgley, Ghormley, Gudakunst, Ivy, Karsner, Lee and Viets 1945, Duvall 1948, Hellebrandt, Skowlund and Kelso 1948, and McBride 1950). In clinical work, for example, accurate measurements are important in diagnosis and prognosis and as a guide to treatment and its effects. They also serve to record the ultimate functional recovery or the residual disability and are particularly useful in deciding when treatment should cease. Repeated measurements during treatment were recommended by Albee and Gilliland (1920) in order to arouse and maintain the interest of the patient in the progress of his own case; under the term " metrotherapy " they included it as a definite part of treatment. Wiechec and Krusen (1939), considering the amplitude of movements, also supported this view. We have found that patients show great interest in frequent accurate measurements of the strength of a muscle group or the amplitude of a movement.

In industrial accident cases, accurate records may be required of the extent of the injury and the degree of functional disability. The just award of compensation may depend on the accurate assessment of the degree of disability (Rosén 1922).

Accurate measurements on normal subjects are of fundamental interest in the study of joint mechanics (Darcus 1951, Salter and Darcus 1952, Darcus and Salter 1953, Salter and Darcus 1953), and may be concerned in specific problems which have their application in clinical work (Darcus 1953). Accurate data are also of value outside the clinical field; normal

values for the strength and amplitude of movements have become of increasing importance in the design of equipment and machinery. Certain tests of muscle strength have also been incorporated in series of " physical fitness " tests used by the Services. Yet for whatever purpose measurements are made, they can only be as useful as they are reliable.

ADVANTAGES AND DISADVANTAGES OF SUBJECTIVE AND OBJECTIVE METHODS

The earliest methods of measuring muscle strength and the amplitude of joint movements were subjective—that is, they were dependent on the personal impressions of an observer. The need for reliable and more accurate methods has led, in many cases, to the replacement of subjective estimation by more objective methods, which make use of an independent means of assessment, thus eliminating so far as possible the human element. However, subjective methods are still used in clinical work, and it has been stated that no amount of objective measurement of work capacity can be substituted for the subjective estimation of an experienced surgeon (Milch 1945). The advantages of objective methods mentioned below, however, warrant the use of quantitative measurement in conjunction with personal impressions wherever possible.

The main disadvantage of a subjective method is that it is crude; there can be no fine discrimination between different levels of muscle activity. For this reason it is of little or no use as a quantitative measure in fundamental or applied problems and has certain disadvantages in clinical work. Impressions gained from observing muscle and joint action may vary from time to time in the same observer and almost certainly do vary in different observers. This may lead to incorrect conclusions, particularly if the rate of recovery in a patient is slow; and it is therefore essential in the personal assessment of joint and muscle function for consecutive tests on any one patient to be made by the same observer. Discussing these disadvantages, Lovett and Martin (1916*b*) stated: "Impressions that electricity of one kind or another, or rest, or exercise were beneficial have filled the literature; unsupported assertions, marvellous cures and fantastic treatments have too often been advanced on the slenderest of grounds." A further disadvantage of the subjective method is that, since there are necessarily few levels of function that can be distinguished, recorded improvement is slow and the patient therefore derives little encouragement from the tests. An advantage of considering only a few functional levels is that any one grade is wide enough to cover incidental variations.

The main advantages of a subjective method are that it is quick and requires no apparatus, and it can be used for any muscle or joint in individuals of any age. In the assessment of muscle strength, the empirical index of function that it provides has the appearance of being complete in itself and of requiring no comparison with a table of normal values as do numerical results.

In contrast, the objective method may be time-consuming and relatively expensive and yields results which require comparison with a standard. A further disadvantage that may arise in objective testing if an instrument is used for any length of time is that training or fatigue may affect the results. The importance of these factors may possibly be assessed if measurements are taken on the normal side for comparison.

The main advantage of the objective method is that it is reliable and, since measurements can be taken to the required degree of accuracy, the method has a wide application in studies on normal individuals as well as in clinical work. Furthermore, small increases in muscle strength or amplitude of movement can be demonstrated, which is important in providing encouragement to the patient as well as useful information for the clinician. Milch (1945) pointed out that objective methods can provide readings which may be accurately compared with further readings taken on the same individual at different times. This is one of the most important advantages of such methods, since the rate of recovery, effect of treatment, etc., can be assessed.

From the following discussion it will be seen that the general trend is from simple subjective methods to more accurate and complicated objective methods, and that, whereas the former provide valuable information in routine clinical work, more reliable means have been evolved for the accurate study of clinical and applied problems. One point of great importance must be stressed: whether the tests made are subjective or objective, it is essential that the results are recorded accurately and intelligibly.

METHODS OF MEASURING MUSCLE STRENGTH

Probably no single method of determining the strength of individual muscles or muscle groups can be used for every circumstance in which such observations are required. Any method, however, must allow reliable recordings to be quickly and easily made and must be adaptable to the measurement of as many muscle groups as possible.

SUBJECTIVE ASSESSMENT OF MUSCLE FUNCTION

Clinical assessment of muscle strength was originally based on purely subjective methods. The degree of muscle contraction was estimated manually and the muscles graded as normal, partly paralysed or totally paralysed. The partly paralysed group included muscles ranging from those that were nearly normal to those producing only a flicker of contraction. The limitations of this method are obvious. This test was amplified by the estimation of the amount of pressure that had to be applied to prevent a movement occurring. A certain degree of objectivity in grading intermediate levels of activity was provided by adopting the following system for muscles whose action is affected by gravity: *None* = no evidence of contractility; *trace* = the muscle can be felt to tighten but cannot produce movement; *poor* = movement with gravity eliminated; *fair* = movement against gravity; *good* = movement against gravity and some resistance; *normal* = movement against gravity and a greater resistance.

This scheme was first put forward by Lovett (1916), and since that time the different levels of function have been given various numerical values. Legg (1936) and Nelson (1947) used values from 0 (normal, or no paralysis) to 5 (complete paralysis), and Kendall and Kendall (1949) modified the scheme slightly and graded muscle strength as a percentage of normal. The grading most commonly used in Great Britain is that proposed by the Medical Research Council in 1942 (M.R.C. Memorandum No. 7)—namely, from 0 (no contraction) to 5 (normal). This method is widely used in clinical work and has the advantage that it provides an empirical measure of function and can be applied to any muscle group in the action of which gravity is important, and in individuals of any age. However, the method is not clearly defined; for example, a muscle may be able to overcome gravity plus some external resistance through part of its range, but may not be able to complete the range of movement even against gravity alone. Also, in practice, muscles are graded as 5 (normal) when they can function adequately, although in fact they might compare unfavourably with unaffected muscles. Thirdly, no standard techniques are adhered to. The following example is given of two methods of grading the quadriceps muscle which were used in the same hospital: 1) The knee is fully extended and the patient is required to maintain this position against applied resistance attempting to flex the knee. 2) The knee is flexed to a right angle and the patient attempts to extend it against resistance applied to oppose the movement. Finally, the manual testing method is of no use for grading muscles whose action is either not affected by gravity, such as the abdominal muscles, or which do not normally act alone, such as the brachialis. Subjective methods in general are of little or no use for studying the strength of normal muscles under different conditions.

OBJECTIVE METHODS

The methods and instruments to be described have been devised for the measurement of strength of individual muscles or muscle groups and for the assessment of muscular efficiency as a whole. Complicated ergometers for determination of energy expenditure

during prolonged periods of work involving large muscle groups, and instruments designed primarily for specific experimental work are not described; neither is the use of electromyography. The different methods to be described can be roughly classified into four types: spring-balance methods, pressure systems, ergographic techniques and strain-gauge methods.

Spring-balance methods—From the subjective methods for grading the functional activity of partly paralysed muscles and muscle groups evolved the first objective method for the large-scale determination of muscle strength. The subjective estimation of the amount of resistance necessary to prevent a movement was replaced by a quantitative measure recorded on a spring balance. One of the main differences between this and other tests of muscle strength that have been proposed is that the part played by the subject is to resist a pull rather than to exert his strength in active effort. This method was suggested and developed by Lovett and Martin (1916*a*) and was the first simple technique for objective muscle testing to be widely used in clinical work, although the principle of the method had been put forward and a suitable instrument devised by Duchenne in 1863 (Bullard 1886). The method, employing a simple spring balance, was able to show in muscles a slight degree of function not detectable by other means, and more accurate quantitative values could be obtained to demonstrate the course of recovery under different kinds of therapy. A sling adjusted round the limb was attached to an accurate spring balance which measured the resistance applied in order to prevent the limb moving from a standard position. The authors drew up a standard technique for the major muscle groups and compiled a table of " normal " values for varying ages (Martin 1921).

A similar spring-balance technique was used in an experimental study by Haxton (1944) and in clinical work by Lewey, Kuhn and Juditski (1947). The latter workers validated the use of their method by comparing the strength of muscle groups expressed as a percentage of normal, with the amplitude of the electromyogram obtained from maximal electrical stimulation of the nerve also expressed as a percentage of normal. Schmier (1939) used a modification of the method of Lovett and Martin incorporating an ink-writing pointer and appliances for the stabilisation of the patient. Later he further modified and elaborated his method, using a gravity lever scale similar to that used by Mayer and Greenberg (1942) (Schmier 1945). These workers had criticised the technique of Lovett and Martin, stating that a spring balance permits too much subjective variation in the hand of different examiners and too great a range of body motion, with a consequent shift of the angle of force and a variation in the strength of contracting muscles.

Clarke, Elkins, Martin and Wakim (1950), in a study of normal muscles, measured the amount of tension applied to a cable appropriately placed for specific movements as in Lovett's method, with a specially adapted and calibrated tensiometer. This instrument works on the spring principle but is geared to be sensitive to contractions which are almost isometric. Using springs, Rudd (1951) developed a dynamometer which could be used for the measurement of hand and finger strength and also for resistance exercises.

Two instruments commonly used in physical fitness tests as well as in clinical and anthropological work are the hand-grip dynamometer and the oval-spring hand dynamometer. Both these instruments incorporate a spring system but, as well as the disadvantage common to such systems (see below) they are limited in use, for they can be used only to measure the power of the hand grip and they are not adjustable for hands of different sizes. Regnier (1807) (cited by Bullard 1886) was the first to devise a hand dynamometer of the oval-spring type. A more compact instrument was developed by Mathieu and by Robert and Collin about 1870 (Bullard 1886) and has been extensively used with only minor modifications. The disadvantage of using the grip dynamometer as an index of general strength was noted by Martin and Rich (1918): the subject uses one of the most complex musculatures of the body and one which receives much special training. The test therefore reflects conditions to an exceptional

degree. However, the instruments are simple and easy to use and adaptable to a wide variety of test circumstances.

The following disadvantages of a spring-balance system were noted by Wakim, Gersten, Elkins and Martin (1950): a spring has a high internal resistance, a low range of sensitivity and a changing sensitivity. The fact that any spring can only work over a limited range of sensitivity is probably the greatest disadvantage. A further disadvantage in any instrument involving the compression or extension of a spring is that there is an increase in resistance towards the end of the range of movement—that is, at the stage where the muscle is least able to overcome it. A disadvantage of this and the following two methods of objective muscle testing is that they cannot be used to test muscles which, while not completely paralysed, are too weak to produce movement.

Pressure systems—Another group of instruments devised for the objective measurement of muscle strength act by means of a system in which pressure changes occur. Most of these were designed to measure the strength of hand grip. The earliest dynamometer of this type, involving compression of a rubber bulb which causes coloured water to rise in a graduated tube, was devised by Hamilton in 1875 (Bullard 1886). Fox (1917) described a similar instrument, which Amar called a " dynamographic pear," in which the pressure change could be read directly off a scale or recorded kymographically. Modifications of this simple apparatus were used by Brahme (1936) and Schwab (1953), while Hellebrandt, Houtz and Kelso (1950) developed a complex instrument incorporating a pressure system, changes in which activated the lifting of weights.

Tarbell (1950) described a " digit myometer " made for measuring small gains in finger strength after injury. Its main advantage appears to be in its simplicity; the strength of the finger is proportional to the increase in height of the column of mercury in an ordinary sphygmomanometer, pressure being exerted on a lever by the finger and transmitted to the cuff through a metal plate. A similar principle was used by Lewis, Pickering and Rothschild (1931). Newman (1949) designed a myometer which could be used for most muscle groups. The instrument consists of a pressure gauge and measures the resistance offered by a muscle in isometric contraction; the reading on the gauge is proportional to the force necessary to overcome the isometric contraction of the muscle under test. The gauge is set in a small cylinder, from one end of which extends a short shaft and a pressure-transmitting button. A built-in hydraulic pressure converter transmits the linear force exerted on the button to the pressure gauge.

Ergographic methods—These involve simple graphic representation of repeated muscular exertions against a resistance provided usually by weights or springs. Instead of giving a single value for maximum muscle strength at any one time, this method provides a record showing the rate of onset of fatigue with a load that may be initially maximal or sub-maximal. In this way the endurance of a muscle or muscle group can be tested and the total work done during a known period of time can be calculated, thus indicating the functional capacity of the muscle or muscle group (Molander and Weinmann 1942). A disadvantage of the method is the length of time required for testing, which makes it impracticable for routine clinical work. However, the instrument can also be used for therapeutic exercise.

The original weight ergograph for recording finger contractions was devised by Mosso (1890) for experimental studies on fatigue. The ergograph record was made with a pen carried by a small block which moved along a horizontal track. On flexion of the finger, a string fastened to it by a leather sling moves the block together with weights attached by a cord and passing over a pulley. This principle has been used more recently by other workers in the clinical field (Sonntag 1917, Simon and Simonnet 1938, Kinard and Coleman 1946) as well as for experimental studies (Martin 1921). One objection to the original ergograph is that as the moving part moves in an arc the angle of pull on the weight is continually changing, and therefore it is difficult to calculate accurately the work done by the muscle. Hellebrandt and her co-workers

(Hellebrandt, Skowlund and Kelso 1948, and Hellebrandt, Kelso, Houtz and Eubank 1950) have developed a complex modification of the apparatus incorporating a wheel to the circumference of which is fastened a bar which is activated by the part under study. Thus the angle at which the force is exerted remains constant throughout the range of movement. In this instrument the total distance moved and the number of contractions are recorded independently of the kymograph tracing.

Simple weight lifting has been used in another way as a means of determining muscle strength. Delorme (1945) advocated the use of repeated exertions with gradually increasing loads to find the "one repetition maximum," that is, the maximum load that can be lifted through the full range of movement once only. A disadvantage of taking this as a strength index appears to be that the patient may be fatigued by the time the maximal load is determined (Zinovieff 1951). A further disadvantage of any weight-lifting technique is that there may be dangers in moving heavy loads. If a subject suddenly becomes unable to lift the load, a rapid movement in the reverse direction may cause muscle damage. There is also the danger of falling weights.

Theoretically, the strength of muscles which are too weak to lift even the weight of the limb against gravity can be gauged by determining the weight necessary to assist the muscle and enable movement to take place. In practice, however, it might be difficult to prevent the muscle from playing a purely passive role.

Franz (1901) objected to the weight-lifting type of ergograph because it does not measure isometric muscle contraction. He replaced the lifting of weights by the extension of a spring, and this method was also used by Hough (1901) and Hall (1902) and more recently by Maison and Broeker (1941) and Russell (1952). Some of the pressure-system instruments already described have been used as ergographs as well as for single tests (Brahme 1936, Hellebrandt, Houtz and Kelso 1950, Schwab 1953).

Strain gauge methods—More recent methods for the accurate determination of muscle strength involve the use of electrical strain gauges, the advantages of which are their low inertia and high degree and wide range of sensitivity. In such methods the applied muscle force is allowed to deform metal bars or rings to which the gauges are attached. The deformation causes a change in the electrical resistance of the gauges which can be recorded either on a galvanometer or, after amplification, on an oscillograph or by pens. Ralston, Inman, Strait and Shaffrath (1947) used a strain-gauge dynamometer for the measurement of isometric contraction of human upper limb muscles in amputees. Strain gauges were attached, two on the inner and two on the outer side of a ring set in a cable which was fixed at one end and attached at the other end to the tendon of the muscle under study. Tension on the cable produced changes in resistance of the gauges which were recorded oscillographically. Wakim *et al.* (1950) used this method on normal muscles, the cable being attached by a sling to the extremity being tested. They found results similar to those obtained using the cable tensiometer (Clarke *et al.* 1950). Tuttle, Janney and Thompson (1950) used strain gauges in a hand-grip dynamometer, and Darcus (1953) described a strain-gauge apparatus for the measurement of rotary isometric torques about various joints.

The latter apparatus has recently been accepted for use in a Medical Research Council investigation on the effects of different exercise routines on the strength of weakened muscle groups following poliomyelitis. This dynamometer appears to be highly suitable both for research projects and for routine clinical testing. In clinical work, however, it would supplement rather than replace the 0–5 muscle charting system.

MEASUREMENT OF THE AMPLITUDE OF JOINT MOVEMENT

The requirements of an "ideal" method for determining the amplitude of joint movements are that it should allow the recording of accurate readings which are reproducible by different observers, and that it should be applicable to all limb joints in people of different

body dimensions. If the method demands an apparatus, this should be simple in construction and use and should not interfere with joint movement. Most of the methods so far devised fulfil only a few of these requirements.

The variety of methods described may be broadly divided into subjective assessments and objective measurements with various types of apparatus.

SUBJECTIVE ASSESSMENT

Subjective assessment, which is dependent on visual approximation, was the first method used and is still commonly employed in clinical assessment of joint function. An adaptation of the visual method was provided by Cleveland (1918). He used circular charts on to which the limits of movement of the moving limb itself, estimated by visual means, were transferred. In the centre of the charts were diagrams of the part concerned showing the axis of movement.

Clark (1921) used a more refined modification of the visual method for the measurement of rotary movements. He used a protractor scale arched over the distal end of the rotating limb, with the limb itself serving as an indicator.

OBJECTIVE METHODS

To allow measurements to be made accurately and to be independent of the observer, numerous instruments have been devised during recent years. These have been termed "arthrometers" (instruments for measuring joints), "goniometers" (instruments for measuring angles) or "fleximeters" (instruments for measuring the degree of bending). These may be classified roughly into three types: protractor and pendulum arthrometers and independent methods.

The protractor arthrometer—This consists essentially of two rigid shafts intersecting at a union allowing movement at right angles to their longitudinal axes. A protractor is fixed to one of the shafts so that its centre corresponds with this union; the other can move independently of the protractor and acts as an indicator. The shaft to which the protractor is attached is held or strapped parallel to the longitudinal axis of one part of the limb, the union of the shafts corresponding to the axis of the movement being studied, and the other is held against or strapped to the other part of the limb. The degree of movement can then be measured directly from the protractor scale. Many modifications and improvement of this basic pattern are reported in the literature (Camus and Faidherbe 1915, Manouvrier 1915, Alquier 1916, Fox 1917, Dausset 1919, Albee and Gilliland 1920, Marble 1920, Rosén 1922, Silver 1923, Conwell 1925, Cobe 1928, Parker 1929, West 1945, Dorinson and Wagner 1948). All have been used to measure flexion and extension movements, particularly at the knee and elbow.

Although the error inherent in the construction of these protractor arthrometers is negligible, inaccuracies occur during their use, mainly from their faulty application. Such faults include failure to ensure that the shafts of the instrument are parallel to the longitudinal axes of the corresponding limb segments, and that the axis of the instrument coincides with the axis of the joint. Wiechec and Krusen (1939), however, considered that with a moderate amount of care in positioning, a simple form of protractor arthrometer, such as the one described by Clark (1920), could attain as great a degree of accuracy as a much more complicated instrument.

Wilson and Stasch (1945) have modified the technique of the measurement of joint movement by the protractor method. They made double-exposure photographs of the arthrometer and the limb, first with the joint in the position of maximal extension and then with the joint in the position of maximal flexion. The amplitude of movement was read off from the photograph, which also provided a permanent record. They also used this photographic method without the arthrometer, determining the amplitude of movement on the developed print by running two straight lines from the axis of the joint along the longitudinal axis of

the movable part of the limb in the two positions, and measuring the angle with a protractor. This latter method was found to be particularly useful in observations on the wrist, metacarpophalangeal and interphalangeal joints. These methods do not seem to have any particular advantage over other protractor methods, apart from providing a permanent graphic record, and this is outweighed by the increased complexity of the procedure.

The pendulum arthrometer—This type of instrument consists of a circular scale, to the centre of which is attached a pointer weighted at one end so that it remains vertical while the scale rotates around it. The scale of the instrument is attached to the movable limb, and during movement of the joint the scale moves around the stationary pointer, thus registering the amplitude of movement. Falconer (cited by Fox and van Breeman 1934) appears to have been the first to devise such an instrument for measuring the amplitude of movement of the knee and elbow joints. Similar types for general use have been described by Glanville and Kreezer (1937) and by Hand (1938).

Independent methods—A number of methods which are to a certain extent independent of the subject on whom measurements are taken have been used to study the amplitude of movements. With such methods there is no possibility of the apparatus interfering with normal movement. Two methods are suitable for clinical use.

Wilmer and Elkins (1947), dissatisfied with other methods of measurement of joint movement, devised an arthrometer embodying optical principles. This instrument consists of a transparent circular scale attached to a concave reducing lens. On looking at the limb through the lens and scale, the reduced image of the limb appears on the scale. The skin is marked to indicate the axis of movement of the joint and define the longitudinal axes of the bones forming the joint. The limits of movement are marked on the scale by movable pointers. This method is claimed to have the advantages of simplicity, lack of interference with the movement, and adaptability.

Recently Zankel (1951) has described another method which he terms "photogoniometry." A protractor scale is projected on to the limb of the subject so that the centre of the scale is focused on the axis of the joint. The amplitude of movement is measured from the projected radii of the protractor scale, which coincide with the longitudinal axes of the bones articulating at the joint under consideration. Points may be marked on the skin to facilitate the readings. He claims that it is an improvement on previous methods because it is more accurate and more susceptible to duplication by different observers, although he gives no evidence for this. He also contends that this method lends itself better to teaching because many different observers can study the same joint measurements concurrently.

Other methods that have been put forward involve radiographic and cinematographic analyses of movement, but these were not intended for routine clinical assessment of amplitude. Bakke (1931) studied movements of the vertebral column by serial radiographs, and Harris and Joseph (1949) used radiography to measure the degree of extension of the metacarpophalangeal and interphalangeal joints of the thumb. Weddell and Darcus (1947) and Darcus (1948) studied the amplitude of composite movements of the neck and spine by the analysis of a ciné-film record. Cinéradiography has been used to study movements of the lower limb (Barnett and Napier 1952) and may be of value in determining the amplitude of complex movements.

A review of methods used to measure the amplitude of rotatory movements of the upper limb was given by Darcus and Salter (1953).

In conclusion it can be seen that, despite the efforts made by numerous workers to devise an arthrometer fulfilling all or nearly all of the requirements, there is still no widely accepted method. If used with sufficient care, it would seem that the simple protractor type of arthrometer is the most generally useful, since it provides adequate information on most joints. Where more precise measurements are necessary, a radiographic method is to be recommended.

FACTORS TO BE OBSERVED IN THE USE OF APPARATUS AND METHODS DESCRIBED

In connection with the use of both objective and subjective tests for the measurement of muscle strength and the amplitude of free movements, there are certain factors which merit attention and consideration. The following points are put forward to illustrate the confusion that is liable to arise when, for example, different terminologies are used, and to provoke suggestions and perhaps some measure of standardisation which would be of benefit in this field of study. It is hoped also that the discussion will demonstrate the importance of indicating in case records and published results the exact technique and procedure of a test so that adequate data are available for those wishing to repeat the study or to use the results for comparative purposes. The factors considered here, although there may be others equally important, are posture, test procedure, standards for comparison, nomenclature and normal variability.

Posture—In the assessment of both muscle strength and the amplitude of joint movements, it is necessary to standardise, or at least to specify, the posture of the body and the precise position of the joints under study as well as those of associated joints. It is essential that these positions should be the same on successive occasions on which measurements are made in order to be able to compare readings taken from the same part in the same individual at different times. The position of the body—for example, sitting or lying down—is important from the point of view of comfort and relaxation of the patient and in so far as it affects the position of the limbs. Fox (1917), stressing this point in the measurement of the amplitude of movement, gave as an example the increased flexion of the hip allowed by flexion of the knee which reduces the " ligamentous " action of the hamstring muscles. Similarly the amplitude of dorsiflexion of the foot is restricted by extension of the knee due to the " ligamentous " action of the gastrocnemius and the amplitude of flexion of the metacarpo-phalangeal joints of the hand by flexion of the wrist due to the ligamentous action of the long extensors. The results of Cobe (1928) show also that the position of the radio-ulnar joints influences the amplitude of abduction and adduction of the wrist.

Experimental studies on the effect of joint position on muscle force (Franke 1920, Hansen and Lindhard 1923, Hvorslev 1928, Garry 1930, Müller 1935, Haxton 1945, Dern, Levene and Blair 1947, Hugh-Jones 1947, Clarke, Elkins, Martin and Wakim 1950, Wakim, Gersten, Elkins and Martin 1950, Wilkie 1950, Darcus 1951, Salter and Darcus 1952) show how important is the consideration of individual joint position in the assessment of muscle strength, whether this assessment is subjective or objective, and for clinical or fundamental work. Posture is also important in the use of the simple and commonly used spring-balance dynamometers, and results of different workers may be of little value for comparison unless standard positions are adopted. This is important, for example, in the " lumbar pull " test which is widely used to obtain an index of general strength. In this test the subject holds the dynamometer handle and pulls vertically upwards, keeping his arms and legs straight. Vernon (1924) had shown that there is an optimum height for the handle below or above which the force diminishes considerably, and after experimental investigation Bedford and Warner (1937) found that the greatest pull was exerted when the handle was at the height of the subject's finger tip.

No standard posture has been advocated for the use of the hand-grip dynamometer. The subject is usually instructed to hold the instrument where he feels that he can exert his greatest force. Fisher and Birren (1946) found that supporting the instrument with the other hand affected the results considerably. It is possible that using a standard posture for the test may also affect the results.

In all muscle testing, both for strength and amplitude of movements, it is necessary to specify the part played by the force of gravity in assisting or resisting movement. It is also necessary to prevent, or at least to be able to detect, substitution or " trick " movements so that one is sure what muscle or muscle groups are acting.

Most accurate results of objective muscle testing would be obtained in the positions of associated joints which normally allow the greatest force to be exerted. This information is available for certain muscle groups (Clarke *et al.* 1950, Darcus 1951).

Test procedure—In all muscle tests the question arises of how many observations should be made on a single occasion. More than one reading is usually taken to avoid chance inaccuracy. Hellebrandt, Parrish and Houtz (1947) showed that an increase in the strength of muscles, which had undoubtedly occurred, was not reflected in tests involving only one reading on a spring dynamometer. They attributed this to the many uncontrollable variables which may influence an isolated observation. However, a study of the reliability of the single muscle test was made by Duvall, Houtz and Hellebrandt (1947) and they found that a single reading is as reliable as the best of three or the best of ten. For clinical measurements of joint amplitude three readings are usually taken. Common methods in the measurement of muscle strength are to take the mean of two or three observations or the best of three; these probably evolved as being the most convenient and the least time-consuming. Doubting the reliability of the "best of three" method, Fisher and Birren (1946) tested the following procedure with a hand-grip dynamometer: scores were taken at three-second intervals with the subject starting at 27 kilograms and increasing by increments of 3 kilograms until his limit was reached. The load increment and the time interval were chosen arbitrarily. Re-test performance showed this to be a reliable procedure and the authors gave it the following advantages: it allows a "warming up" to take place, and the cumulative fatigue ensures the final effort being made under a standard stress. A similar technique was used by Delorme (1945) in clinical work; his subjects worked with a gradually increasing load until a standard number of contractions could not be attained. In considering the number of readings to be taken, the relative importance of fatigue and "warming up" must be noted. The best time interval between successive recordings must be determined, and we have found that five maximal voluntary exertions spaced at intervals of one minute produce little or no fatigue. The speed of making a single exertion—that is, the time over which the maximal force is built up in the muscle, must also be considered. Studies carried out by Hill (1922) indicate that the work done in a single maximal effort increases with increasing time taken to build up the contraction—that is, with decreasing speed of contraction. This is due to the fact that the more rapidly a muscle shortens the more potential energy is used up in overcoming the viscous resistance of the muscle. However, there is an optimal economical speed of working related to maximal efficiency.

In ergographic techniques the question arises of the rate at which maximal contractions should be made. This is determined partly by the movement under consideration and partly by whether or not the muscles are normal. Common time intervals are one, two or three seconds. One bout to complete exhaustion may be recorded or a standard number of contractions may be performed and repeated after intervals of known duration. Foltz, Ivy and Barborka (1942) recommended the use of double work periods, each to exhaustion, with a standard rest pause between. The advantage of this method is that, as well as the total work done, the percentage recovery is obtained.

Standards for comparison—In clinical work some standard for comparison is required when measuring either the force in a paretic muscle or the limited amplitude of movement of a joint. As a standard the corresponding measurement taken on the contralateral limb may be used, if this is normal, or reference may be made to a relevant table of "normal" values. So-called normal values for the amplitude of various movements are to be found in the literature (Clark 1920, Gilliland 1921, Rosén 1922, Silver 1923, Frescoln 1929, Sinelnikoff and Grigorowitsch 1931, Coulter and Molander 1935, Glanville and Kreezer 1937, Dorinson and Wagner 1948). Gilliland's values were obtained from "100 observations on male students." However he does not specify the number of observations on each joint. Glanville and Kreezer (1937) studied a number of joints in ten subjects, and the values given by Sinelnikoff

and Grigorowitsch were obtained from 396 male and 118 female subjects. The other workers mentioned give no indication of how their values were obtained or of the size and characteristics of the group of subjects. Such " average " or " normal " values are of limited use, particularly if the range of values which can be considered normal is not given, and, in fact, the values given by different authors for the same movement differ from each other considerably (Darcus and Salter 1953, Salter and Darcus 1953). A more accurate yardstick for the normal amplitude of movement of a joint is probably the contralateral limb, when this is available for study. That there is little difference between the normal amplitudes of certain movements on the right and left sides has been stated by Gilliland (1921). Cobe (1928) and Hewitt (1928), studying the amplitude of movements at the wrist, found differences between right and left sides of over 200 per cent in some cases, but bigger differences were found between individuals, and variations of over 100 per cent were recorded in taking the same measurement on the same individual on different days, suggesting faulty apparatus or technique. Patrick (1946) stated that the range of pronation and supination in both forearms of a single individual is identical. Darcus and Salter (1953) found that the mean difference between the amplitudes on the right and left sides in eight normal subjects was 3 per cent, in contrast with a difference of 20 per cent between subjects.

Considering the measurement of muscle force, Lewey, Kuhn and Juditski (1947) put forward the following objections to using the contralateral side as a standard for comparison: 1) the time of the examination is doubled; 2) there may be a compensatory increase in muscle strength on the normal side; and 3) values on the right side may be higher than on the left side in right-handed subjects. Although the time of testing is doubled, readings taken on the normal side are an advantage in that they reflect normal variations (Darcus 1951, Salter and Darcus 1952). Variations due to psychological, physical and environmental factors can be taken into account in assessing the affected side, as can training and fatigue. At present, comprehensive tables of normal values suitable for comparison under particular test conditions do not exist. Individual variation is so wide and dependent on so many factors (age, sex, physical characteristics, occupation, etc.) that a great deal of work would be necessary to compile adequate information. Using such information, one can only say that a patient falls within the limits of normal variation for his age and sex group or is approximately *x* per cent of "normal." Lewey *et al.* (1947) gave a table of normal values for twenty-three muscle groups compiled from observations on a random sample of hospital patients showing no nerve or muscle weakness. They give mean values and standard deviations but omit to give the number of subjects used and their ages, merely stating that the group includes manual and clerical workers and both right- and left-handed persons. They claim to have obtained more satisfactory results using this table than by using the contralateral limb as a yardstick, despite the fact that overall variation between different individuals appears to be much greater than that between right and left sides in a single individual (Provins 1955, Provins and Salter 1955).

Nomenclature—To be of value, records must be uniform and if possible self-explanatory. Difficulties involved in assessing early work on the measurement of joint amplitude included the wide disagreement in nomenclature, which made results liable to misinterpretation. Each author adopted his own nomenclature, often without specifying what he meant by the terms used.

Most workers appear to agree that all measurements should begin from a neutral point, but there is considerable difference of opinion as to where in the whole arc of movement this should be. Usually it is placed at an assumed mid-point or at one or other end of this arc. If the neutral point is at the assumed mid-point, differences are found in the angular value given to this point and in the system of denoting degrees of movement on either side of it. The difficulties of interpretation arising from this lack of consistency are indicated by the figures given by different authors for the amplitude of flexion and extension of the wrist (Table I).

The meaning of these figures is apparent only when their graphic representation is studied (Fig. 1).

Further confusion arises through the different methods of describing a movement. For instance, in joints allowing extension beyond the point at which the bones are in line, the movement beyond this point is sometimes referred to as hyperextension. Abduction and adduction of the wrist are also described as radial and ulnar deviation or flexion. Movements of the shoulder joint are either defined in relation to the main axes of the body or to the axes of the scapula (Johnston 1937).

The first attempt to clarify the nomenclature was made by Clark (1920). He suggested that the angle included between the bones on either side of the joint should be used to express the limits of motion or angle of deformity; thus complete extension of the knee or elbow would be 180 degrees. However, modification of and additions to this scheme for the measurement of abduction, adduction and rotation made it unnecessarily complicated, and it was not generally accepted. Rosén (1922) believed that measurements from a neutral point were not satisfactory and suggested that the angle subtended at the joint axis by the two extremes of excursion of the joint was more suitable. Silver (1923) proposed that " mensuration of the degrees of motion in joints must start from a zero plane. The zero plane should be considered to be an extension of the plane of the long bone or bones immediately

TABLE I

FIGURES OF DIFFERENT AUTHORS FOR AMPLITUDE OF FLEXION AND EXTENSION AT THE WRIST

	Flexion (*degrees*)	Extension (*degrees*)	Hyperextension (*degrees*)
Clark (1920)	100	180	120
Robinson (1921)	110	115	
Rosén (1922)	135*	225*	
Silver (1923)	70	70	

* These figures were not intended to represent the complete amplitude.

proximal to the joint in question." This method had previously been used by Robinson (1921). Cave and Roberts (1936) merely stated that " all movements should be measured by degrees from a neutral point or zero which must be defined." West (1945) measured all movements on a circular scale graduated from 0–360 degrees, using the position of the joints in the anatomical position as a neutral position. Flexion was measured towards 0 degrees and extension towards 360 degrees.

Dorinson and Wagner (1948) put forward another suggestion in order to " facilitate recording and obviate any misinterpretation." They state that " if, for an example, a patient has a 10 degrees' flexion contracture with a range restricted to 40 degrees, this would be obvious by the recording of ' extension-flexion ' 170–130 degrees." So far as is known, this suggested method has not been applied to any extent.

It is evident that there is still as much disagreement as ever concerning nomenclature, and that until a universal method is adopted each author must specify exactly which angle he is in fact measuring and which neutral point he is using. To avoid ambiguity, it is stressed that graphic representation of the results should supplement the written description (Cleveland 1918, Nutter 1919, Parker 1929). It is also important to state whether the movements measured are active or passive. The results of Glanville and Kreezer (1937) indicate that the difference between the amplitudes of active and passive movements in normal individuals

may be 10 per cent or more, and it is felt that this question deserves further investigations. In clinical conditions the difference may be much larger and, while this is well known, no objective clinical study on the subject has been found.

Similar confusion is less likely to result from work on the measurement of muscle force, providing that the units and the point of application of force are clearly defined, so that only strictly comparable values are in fact compared. Static activity cannot be compared directly

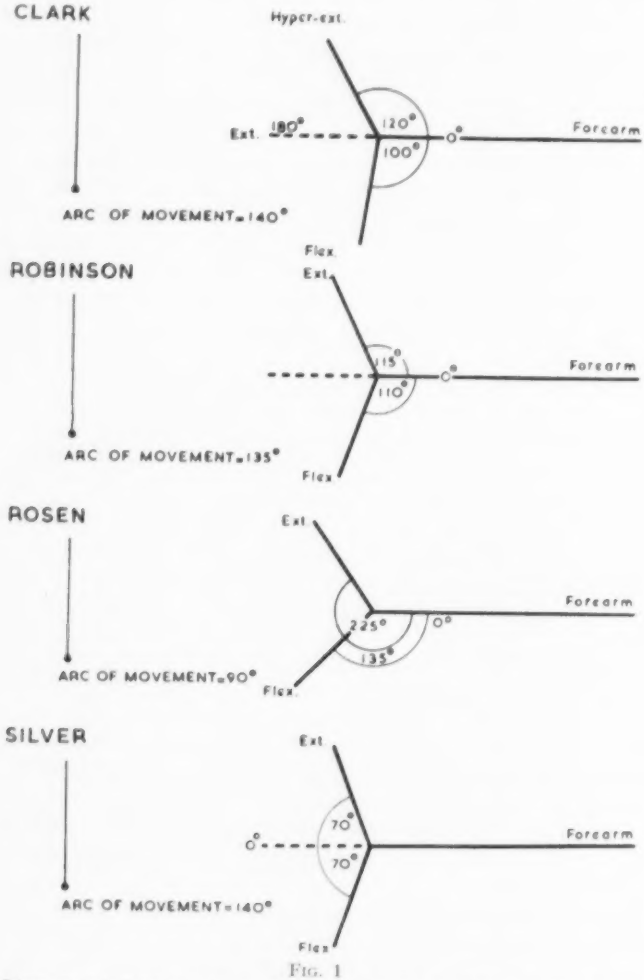

FIG. 1

Diagram to indicate the nomenclature and systems used by various authors to denote the degree of flexion and extension of the wrist.

with dynamic work because the units are different. Starr (1951), however, has devised a mathematical method of expressing the two components in experimental weight lifting in the same units.

In manual muscle testing in Great Britain muscles are graded numerically from 0 to 5, 0 indicating no evidence of contractility and 5 a normal muscle (Lovett 1916, Medical Research Council Memorandum No. 7,1942). It was confusing to find in two American papers the same

functional levels given different numerical values (Legg 1936, Nelson 1947). These numerical values may be misleading as they bear no relationship to absolute levels of muscle strength. For example, a muscle of grade 4 is not twice as strong as a grade 2 muscle.

In order to avoid difficulty in the interpretation of results, it is stressed that the exact procedure should in the first instance be described.

Variability—Considerable variation is found in measurements of muscle force and of amplitude taken on different occasions in the same individual (Darcus 1951, Salter and Darcus 1953). Such variations will occur in injured as well as normal individuals, and the clinician will wish to know how big a change in muscle force or amplitude must be before it reaches practical significance. A dramatic and maintained improvement offers no problem, and small changes which are insignificant in themselves become significant when they are reflected in the trend of a series of tests made on successive occasions. However, in order to increase the accuracy of assessing any improvement, normal variability should be minimised so far as possible.

Of environmental factors, temperature and possibly humidity and barometric pressure may affect muscle strength. Probably temperature is the most critical, though it can most easily be controlled. Lovett and Martin (1916*b*) noticed that during "the great heat of September 1915" there was a decrease in muscle strength in several persons whose normal values were known. The temperature of limbs is important in testing muscle strength, particularly after poliomyelitis. Lombard (1892) concluded from his experiments that the time of day and barometric pressure influences muscle strength, and the latter has also been suggested by Fischer (1947). These factors have not been proved to have an effect, but the time at which tests are made could perhaps be standardised for each subject.

Distractions to the patient and to the observer should be avoided, concentration on the test maintained and motivation standardised as far as possible. In clinical work the incentive is usually high, particularly if the patient is allowed to watch the readings being taken and to follow the results of the test (Albee and Gilliland 1920). The willingness to exert a maximal effort when this is required may markedly affect the results, and there is no simple objective method of distinguishing between the physiological and psychological end points of effort. The interest and co-operation of the subject should be sought. This is particularly important in experimental work with normal subjects, because boredom and antagonism would give inaccurate results and wide variation within groups of readings. Individuals being tested should be instructed to relax "mentally" as well as physically, for apprehension or anxiety may affect the degree of muscle tension (Jacobson 1946, Barlow 1947, Lundervold 1952). The necessity for rigid control of environmental, physiological and psychological factors is emphasised by Taylor and Brozek (1944). Factors which could be to some extent controlled in hospital patients, but which are difficult if not impossible to control in other subjects, are the amount of rest and the amount and type of activity and exercise. These factors may affect readings taken at long intervals or over extended periods. Pain may limit the degree of muscle contraction in clinical cases and must be taken into account when relevant. If one side of the body is not affected by disease or injury, control tests on this side might help in distinguishing between the effect of environmental factors and factors acting on the affected side alone. Similarly, contralateral tests might assist in the distinction between a training effect in the remaining innervated fibres in a paretic muscle and improvement perhaps due to functional re-innervation of previously denervated fibres.

In summing up this discussion of the importance of test procedure, posture, nomenclature, standards for comparison and normal variability in the measurement of muscle and joint function, it can be seen that a consideration of these factors is essential if the work carried out is to be as useful as possible. Although it is impossible to apply rigid techniques, because modifications are required to meet individual needs, it is considered that there is room for some standardisation, particularly of nomenclature. Until there is a generally accepted system

of denoting the angular position of joints it is necessary for workers to describe accurately the system they use as well as specifying details of posture and test procedure. It is appreciated that time is valuable in routine hospital work, but the little extra time required to specify essential details of the procedure would be well spent. If this is done, future presentation of data will be clearer and more useful than it has been before.

SUMMARY

1. The importance of accurate methods of measuring the strength of muscles and the amplitude of joint movements in man, both in clinical fields and as criteria of normal function, is discussed.

2. The advantages and disadvantages of subjective and objective methods are reviewed.

3. The main types of apparatus used for the assessment of muscle strength in both normal and clinical conditions are described. A dynamometer of the strain-gauge type is recommended.

4. Methods of measuring the amplitude of movements in man are also described. The protractor type arthrometer is thought to be the most suitable for routine clinical work, but for research purposes a radiographic method may be preferable.

5. The following factors, which must be considered if the measurements taken are to be of greatest use, are discussed: posture, test procedure, standards for comparison, nomenclature and normal variability.

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VASCULAR CHANGES CAUSED BY THE KÜNTSCHER TYPE OF NAILING

An Experimental Study in the Rabbit

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In the Nuffield Orthopaedic Centre investigations of the blood supply of bone have been pursued for some time, and methods for the visualisation of the vessels have been published (Trueta 1953*a*, 1953*b*, Trueta and Harrison 1953, Harrison, Schajowicz and Trueta 1953). Part of this research entailed a study of the vascular pattern of fracture callus, and the results of this work are now being prepared for publication. Among the methods used in this investigation was suppression of one or other of the three main vascular sources of supply to the long bones (periosteal, metaphysial-epiphysial, and medullary) because it was known that the interruption of one or two of these sources stimulates those that remain to take over after a varying interval, an effect that is being used in this Centre to stimulate bone growth (Trueta 1950, 1952, 1953*c*, 1953*d*).

During the course of the general investigation into the blood supply of callus the hypothesis was advanced that overproduction of periosteal callus, which has been reported occasionally in man after Küntscher nailing (Küntscher 1940, 1941), could be explained by periosteal vascular proliferation after damage to the nutrient artery by the nail. During the whole of the research on the blood supply of callus special attention was paid to that possibility, and the results of this investigation have been separated from the main body of data collected on the healing of fractures and constitute the present publication.

In the experimental animal, if the circulation of the bone marrow and that of the periosteum are interrupted, an increase in blood flow through the metaphysial vessels is usually observed. On the other hand, if the circulation through the nutrient artery and metaphysial vessels is interrupted, it is the periosteal blood flow which increases. During the course of the present work it was also observed that the proliferation of the periosteal vessels was always followed by new bone formation. When the blood flow through the nutrient artery was interrupted it was noticed that approximately the inner two-thirds of the cortex became ischaemic and subsequently necrotic, but that the outer third always remained alive, indicating that the main blood supply of the outer third of the cortex came across the periosteum. Contrariwise, when the periosteum was stripped and kept detached from the cortex by the interposition of an isolating polythene membrane, the circulation through the nutrient artery having been preserved, only the outer third of the cortex became the site of irregular ischaemia and a large periosteal bone (involucrum) formed round the whole shaft (Figs. 1 to 3).

The correlation between vascular proliferation of the periosteum and bone formation seemed to indicate that the Küntscher method of bone nailing operates through the production of persistent ischaemia of the nutrient artery, in which case vascular proliferation of the periosteum would be responsible for the deposit of new layers of periosteal bone. In the original papers by Küntscher (1940, 1941) and in successive observations by Lauritzen (1949), Erlich (1943), Böhler (1948) and others there is a diversity of opinion about the merits of the

Küntscher nail and its influence on callus formation. A full investigation of this problem was thus considered worth while.

In the course of our previous experiments it was found that when a fracture was produced under circumstances that caused bone marrow ischaemia, union of the fracture took place quicker and the callus was stronger than under ordinary experimental circumstances. As the connections between the terminal branches of the nutrient artery and metaphysial vessels

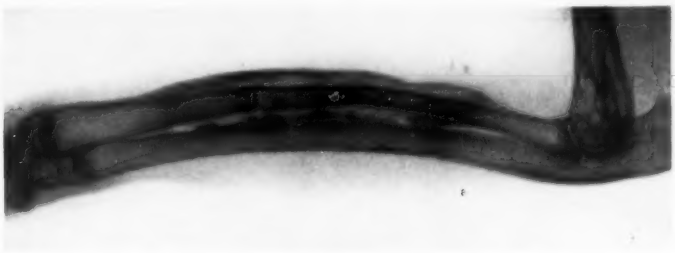


FIG. 1

After division of the radius the periosteum of the shaft was stripped and kept detached from the cortex by the polythene membrane. A large involucrum was formed.

FIGS. 2 and 3

Figure 2—After the removal of the involucrum and polythene membrane an arteriogram showed the preservation of the bone marrow blood flow. The ischaemia of the outer part of the cortex gives evidence of the periosteal origin of the outer cortical blood flow. Figure 3—Very rich injection of the involucrum, whose blood supply was purely periosteal.

are very profuse, in order to ensure persistent bone marrow ischaemia blood flow from the metaphysial vessels towards the nutrient artery was prevented by drilling both ends of the shaft of the bone and plugging the cavities with polythene, a material which constitutes only a mechanical barrier to vascular penetration. After this procedure the circulation through the nutrient artery was not renewed, because at the end of the experiment it was demonstrated by arteriograms that the only remaining blood flow was periosteal (Figs. 4 to 7).

METHODS

Rabbits were used throughout this research, the bone selected being the radius as it was deemed necessary to obtain comparable material throughout the whole series. No immobilisation after the " fracture " was required, the ulna acting as a splint through its connection with the radius by the interosseous membrane. The bone was divided at the same level in all the animals and approximately the same amount of soft-tissue damage and of

periosteal tearing was produced in every case. The bone was divided by a thin Gigli-type saw made from a double twisted stainless steel wire of gauge 40. This was attached to a stouter wire which was threaded on a slightly curved atraumatic needle. A small incision was made on the flexor surface of the rabbit's foreleg, the needle being introduced between the two bones near the lower insertion of the pronator teres to the radius, and pulled through on the extensor surface through a further small skin incision. It was then reintroduced through the same hole round the outer surface of the radius close to the bone. The periosteum was cut transversely on the flexor, medial and lateral surfaces of the radius and the bone was divided

FIGS. 4 and 5

Figure 4—Radiograph of the control side after consolidation. Figure 5—Angiogram showing rich circulation in the bone marrow cavity.

FIGS. 6 and 7

Figure 6—Radiograph of the experimental side after consolidation of the "fracture." To produce a permanent interruption of the blood flow of the bone marrow cavity the two metaphysial ends of the shaft had been drilled and plugged with polythene. Figure 7—Arteriogram showing the absence of nutrient artery at the end of the experiment.

with the saw. In this way the nutrient artery was interrupted every time together with the bone. In a number of animals the same method of bone division was used on both sides, with a nail introduced into the medullary canal on one side whilst the other radius was left undisturbed and used as a control. Several materials were tried for the medullary nails, from ordinary stainless steel Kirschner wires to various sorts of round or corrugated rods made from polythene, a substance which has been shown not to cause bone reaction, a fact confirmed by our histological observations. Polythene was used with the idea of obtaining radiographic information in living animals because it is transradiant.

FIGS. 8 and 9

Figure 8—Control animal radiographed ten days after the production of the fracture, showing moderate callus formation. Figure 9—Experimental animal whose bone marrow had been obstructed with a Kirschner wire, showing more abundant callus than the control ten days after division of the bone.

FIGS. 10 and 11

Control animal (Fig. 10) and experimental animal (Fig. 11) three weeks after the causation of the fracture, showing the more advanced maturation of the callus in the experimental animal. Whereas in Figure 10 the clear endosteal callus is observed, in Figure 11 there is no radiographic trace of it.

FIGS. 12 and 13

Figure 12—Radiograph of a control animal after consolidation of the fracture. Figure 13—Widening of the whole diameter of the bone on the experimental side.

When a Kirschner wire was inserted it was introduced through the articular surface of the radius after opening the wrist joint. Three different thicknesses of Kirschner wires were available, and the size selected was that which could be introduced without excessive difficulty after estimating the width of the canal on the radiographs. The rabbits were arranged in two groups according to age, one of young and the other of fully grown animals.* The method used was the same in both groups. In young animals the nail was pushed through the epiphysis and epiphysial plate.

Radiographs of both the limb operated upon and the control limb were obtained at weekly intervals. At the end of the experiment arteriograms were obtained, usually by injecting Micropaque without removing the polythene.

RESULTS

Apart from the series of experiments in which the nutrient artery was ruptured but no foreign body was left filling the medullary canal thirty-one rabbits were used for this investigation, distributed as follows: Nailing with polythene, twenty-one (nine adults, twelve young); nailing with Kirschner wire, ten (seven adults, three young). The results were basically similar whatever the material used for the nail, but there were some differences between young and adult animals which makes a separate description of both groups necessary.

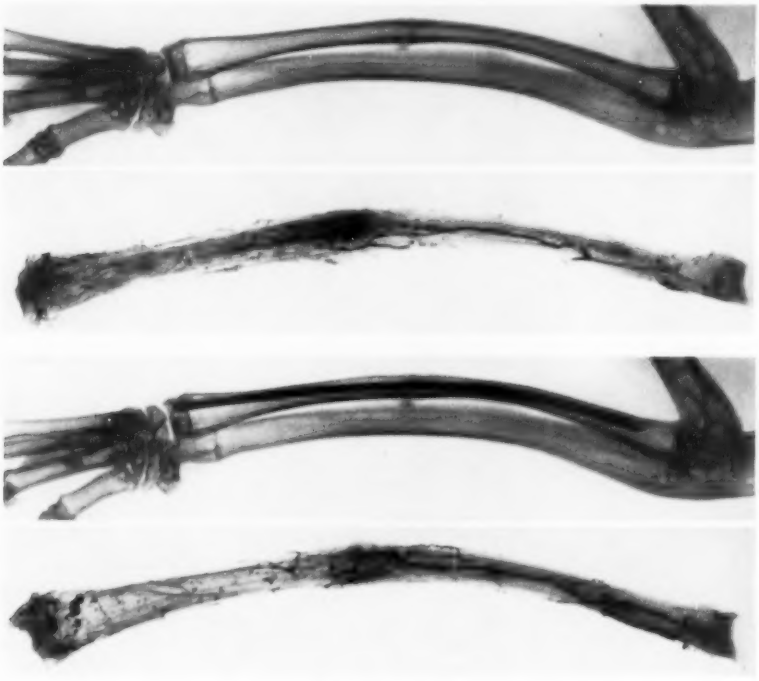
YOUNG ANIMALS

Analysis of the radiographic findings—Between seven to ten days after the introduction of a nail a layer of new bone appeared along the diaphysis, covering it either entirely or to a great extent (Figs. 8 and 9). This new bone is continuous with the periosteal callus and at the outset often does not extend to the very end of the fragments. In the early stages the radiographic appearance of this layer of new bone is cloudy but it soon becomes denser and seems well incorporated in the cortex. This density increases during the first few weeks, but from the second or third week new bone coming from both fragments establishes a continuous bridge across the " fracture " site which unites the two fragments (Figs. 10 and 11). In most of the animals the periosteal callus appears earlier on the nailed than the control side. The size of the periosteal callus which forms the " direct bridge " is never greater and is usually smaller than on the control side, and union is frequently quicker on the nailed than on the control side. As a result of the layer of bone added to the cortex on the experimental side this becomes wider and the whole diameter of the bone increases (Figs. 12 and 13).

In some animals the widening did not extend the whole length of the diaphysis. In these cases the angiograms obtained at the end of the experiment showed that a stump of the nutrient artery had remained in the marrow cavity and that the bone changes extended exactly up to the end of the arterial stump (Figs. 14 and 15). Whereas without exception on the control side advanced endosteal callus existed from the eighth to the tenth day this did not appear in any of the experimental bones. Radiographically the gap in the fracture line disappeared roughly at the same time in both the experimental and the control bones, but when exceptions to the rule were encountered these showed a slightly earlier filling of the gap in the nailed bone than in the control (Figs. 16 and 17). About four weeks after the fracture some changes in the inner cortex began to take place, usually in the ulnar side of the bone, and gradually spread to its radial side. These changes led to a gradual reabsorption of the inner part of the cortex as if it were moving away from the foreign body. In this way the cortex regained its normal thickness but the total diameter of the bone at the end of the process appeared greater than that of the control (Figs. 18 and 19). In one of the animals

* We considered as adult those rabbits whose radiographs showed the lower radial epiphysis fused.

observed for about three months after nailing, the diameter of the bone remained greater than that of the control, the animal having ceased growing at the end of this observation. In another animal changes were observed up to the seventh month, although they were very mild during the last two months. In exceptionally good radiographs it was possible to see that during the first two or three weeks the inner layer of the cortex appeared denser than its outer part.



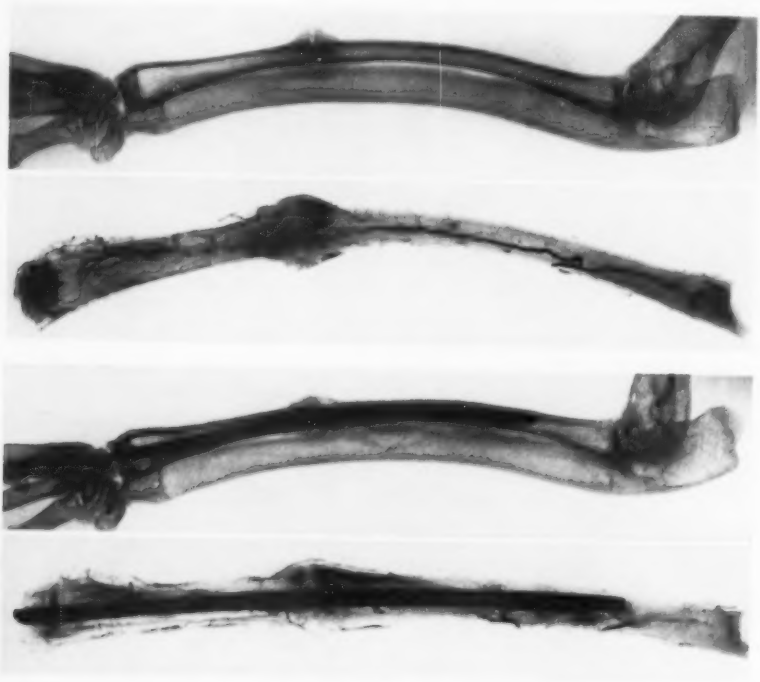
FIGS. 14 and 15

Figure 14—Radiograph and angiogram of the control side. Figure 15—Radiograph and angiogram of the experimental side. The radiograph shows lack of the usual enlargement of the proximal fragment. The angiogram, after removal of the wire, shows the proximal half of the nutrient artery still present.

Study of the angiograms—Every one of the animals was injected to permit vascular studies at the end of the experiment at varying time intervals according to a prearranged plan. A study of the angiograms showed that in most of the cases the nutrient artery was absent, whereas on the control side it was well injected with radio-opaque substance and quite often the two divided parts had reunited through anastomotic vessels across the fracture line (Fig. 20). Occasionally in the nailed bone there was some injection material in the proximal part of the nutrient artery, but usually the stump of the vessel never reached the fracture level and it was always squeezed against one of the walls of the canal. In no case was the distal part of the nutrient artery found injected.

In order to study the vascular pattern of the cortex after interruption of the blood flow from the nutrient artery it was found convenient to remove the periosteum at the end of the experiment to avoid the superposition of periosteal vessels on those of the cortex. As compared with the control side it was found that the small vessels perforating the cortex in the nailed

bone were much more numerous (Figs. 21 and 22). The proliferation of vessels at the fracture site, contrariwise, was practically the same on both the experimental and the control sides. The number of small vessels of this area depended on the stage of the healing and on the type of



FIGS. 16 and 17

Figure 16—Radiograph and angiogram of the control side. Figure 17—Radiograph and angiogram showing the more advanced stage of consolidation on the experimental side.

FIGS. 18 and 19

Figure 18—Radiograph of the control side. Figure 19—Radiograph of the experimental side showing greater diameter of the bone marrow cavity.

the fracture. If the callus was profuse more vessels were apparent. In angiograms of transverse sections of bone 1 millimetre thick, a number of vessels appeared to be perforating the cortex in a rather straight course, while this direction of the vessels was never seen on the control

side except close to the fracture line (Figs. 23 and 24). These cortical vessels were already present twenty-one days after nailing. The trabeculae were laid down following the straight direction of the vessels (Fig. 25). An increase in the vascularity of the cortex was found in all these nailed bones in spite of the early ischaemic lesions in the inner part of the cortex

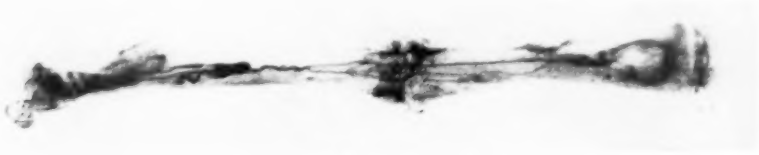
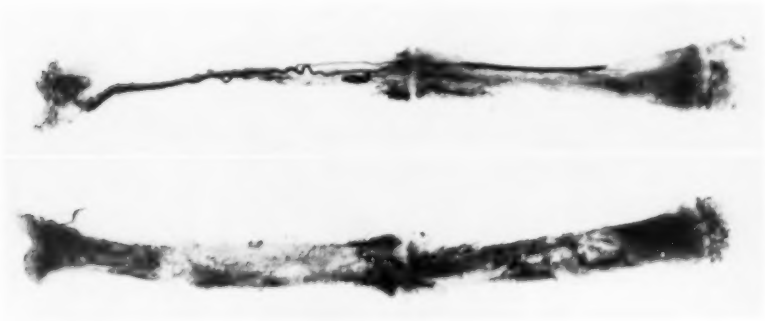


FIG. 20

Angiogram of a control side showing the reunion of the two divided parts of the nutrient artery through anastomotic vessels.



FIGS. 21 and 22

Figure 21—Angiogram of control side at the end of the experiment showing the reconstitution of the nutrient artery and the relatively poor periosteal flow. Figure 22—Total absence of nutrient artery and great periosteal vascular proliferation.

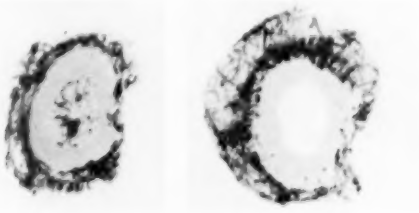


FIG. 23 FIG. 24

Figure 23—Control side of a transverse section of the shaft at the level of the callus showing lack of systematic direction in the periosteal vessels. Figure 24—A large number of periosteal vessels are shown perforating the cortex in a rather straight course towards the bone marrow.

caused by the interruption of the blood flow through the nutrient artery. A substantial amount of the radio-opaque material was usually present in the medullary cavity although the nutrient artery had its blood flow permanently interrupted (Figs. 26 and 27). This was further evidence that the blood supply to the cortex after the interruption of the blood flow through the nutrient artery caused by the nail came from the periosteal vessels.

Histology—As early as two weeks after the "fracture" a continuous layer of new bone was seen covering practically the whole of the diaphysis of the nailed side (Fig. 28). This new bone was formed by trabeculae directed obliquely towards the surface of the cortex and continuous with the periosteal callus. Because of this new layer of bone the total thickness of the cortex was greatly increased in comparison with that of the control side. Opposite to this layer of new bone the old cortex showed extensive necrosis of its inner part, some laminae

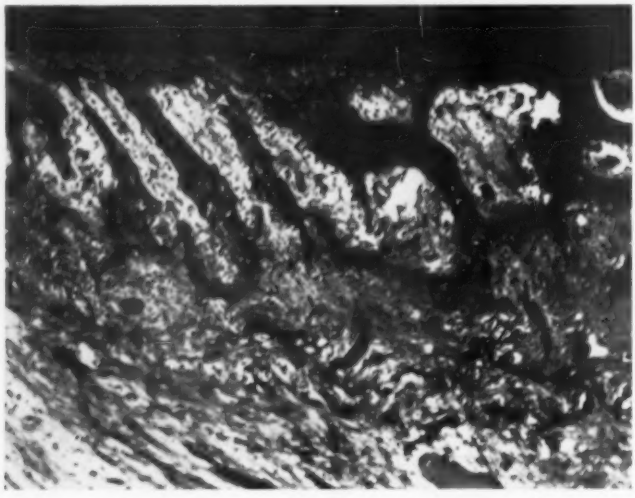


FIG. 25

Straight trabeculae emerging from the periosteal side of the cortex and following the same direction towards the bone marrow as the newly formed periosteal vessels.

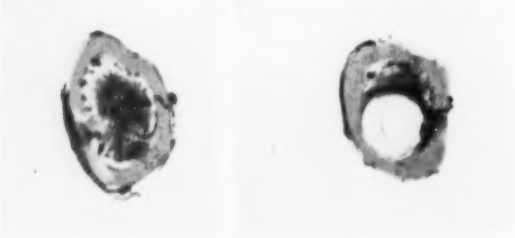


FIG. 26 FIG. 27

Transverse section of the control side (Fig. 26) and of the experimental side (Fig. 27) showing the partial filling of the bone marrow cavity by radio-opaque material in spite of the absence of the nutrient artery.

appearing completely empty of cells and others showing hyperchromatic nuclei. No clear-cut line of demarcation of the necrotic cortex was apparent, but the ischaemic changes affected mainly the inner third of the cortex. Some transformation was going on within the necrotic cortex, such as widening of the Haversian canals and their invasion by new vessels, osteoclasts and osteoblasts. Vessels were seen breaking through the necrotic cortex towards the medullary canal. This revascularisation was taking place much more from the ulnar than from the radial side of the bone (Fig. 29). In fact it has been found throughout this research that removal of the dead bone and its replacement proceeds much more quickly on the ulnar than

on the radial side of the bone. At seven weeks most of the necrotic bone had been reabsorbed, although some dead bone still remained on the outer side of the nailed radius. It was found

FIG. 28

Section of the cortex and periosteum showing the continuous layer of new bone covering the diaphysis of the control (nailed) side, two months after the introduction of the nail.

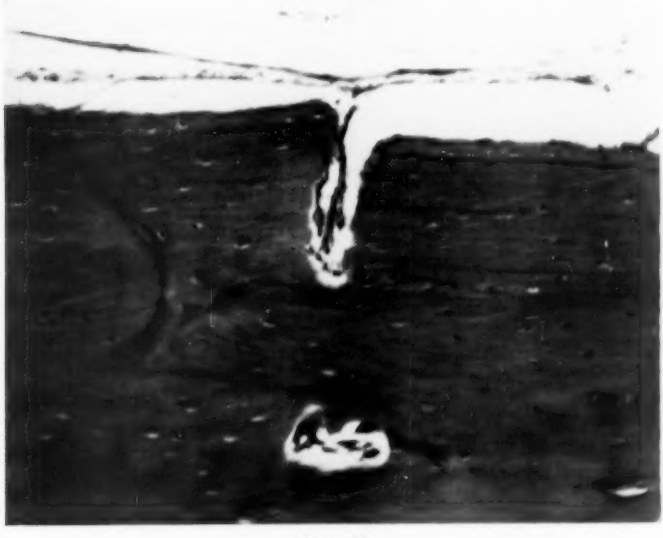


FIG. 29

Vessels from the periosteum breaking through the necrotic cortex towards the medullary canal.

that the fracture had united well through the peripheral callus and by new bone formed between the two fragments after partial absorption of the necrotic ends. No cartilage was

seen in this process of callus formation. The bone marrow became progressively nearer to normal and some new bone formed inside the marrow canal around the nail. In transverse sections through the diaphysis the layer of new bone on the outer surface of the old cortex was seen to be greatly decreasing in thickness but still contained many empty trabeculae on its inner surface. At six and a half months the bone seemed apparently normal and there

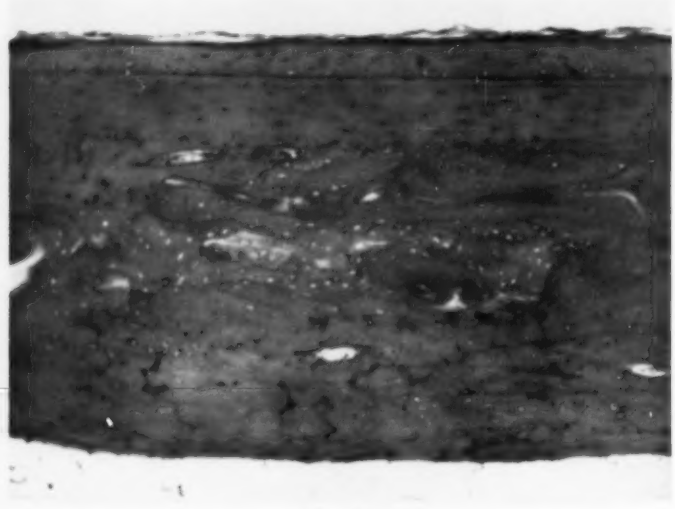


FIG. 30

Extensive bone necrosis still present six and a half months after the introduction of the nail. The necrotic area is now surrounded, mainly on its outer side, by new bone.

was no trace of the previous fracture, but on closer observation there were still several areas of bone necrosis (Fig. 30). A layer of new bone had formed either all around the nail or on one side of it. The marrow showed great cellularity, with many macrophages or giant cells containing lipoid. It appeared well injected and in some places could not be distinguished from the normal.

ADULT ANIMALS

In contrast to the young animals, in the adults it was not possible to find any large mass of new bone covering the outer surface of the cortex. On close observation, however, a slight thickening of the whole of the cortical shaft was seen about two months after the nailing, much later than in the young animals. This thickening was followed by some absorption of the inner cortex which was still continuing after eight months when the experiment was ended. In this way the total diameter of the bone increased here also, although the increase was not comparable with that seen in young animals. It was found that the periosteal callus, as in the young animal, appeared earlier than on the control side in all cases; but in four of the adult animals a much more voluminous callus than had been seen in younger animals was observed (Figs. 31 and 32). It was impossible to determine the reason for the formation of the profuse callus. It was thought that perhaps bone marrow expressed by the nail through the fracture site could have contributed to the formation of this exuberant callus, but why this did not happen in the young animal remains unexplained. The profuse callus was soon absorbed. Finally, endosteal callus did not appear here either. The time of union was similar to that of the control bone and in no case was union delayed.

The disappearance of the fracture line took place at the same time on both the experimental and the control sides. But in the few exceptions encountered it was observed that the nailed bone consolidated slightly earlier than the control.

FIGS. 31 and 32

Figure 31—Control adult animal in which drilling of the metaphysial ends of the diaphysis was effected without destruction of the nutrient artery or plugging with polythene. Figure 32—Experimental adult animal in which the nutrient artery has been divided and its regeneration prevented by plugging the metaphysial ends of the shaft. Note the abundant callus and more advanced consolidation of the experimental side.

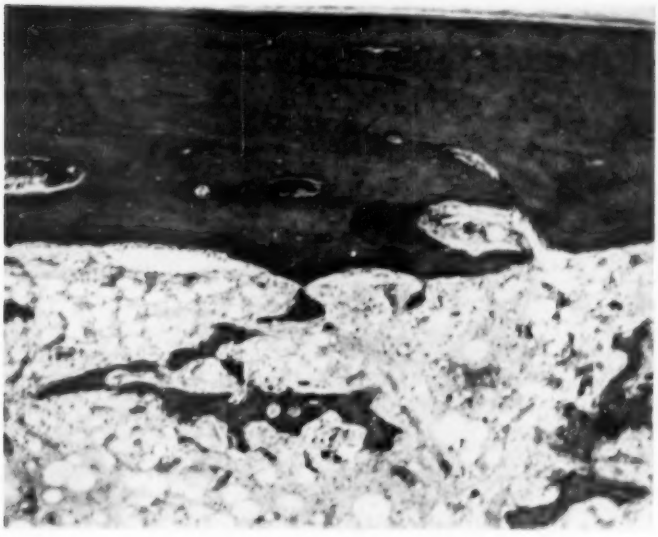


FIG. 33

Necrotic cortex seen in an adult animal eight months after nailing. The inner two-thirds of the shaft are affected.

Angiograms—In no case was the nutrient artery intact and usually it was completely absent. In two animals there remained a proximal stump consisting of part of a proximal branch of nutrient artery. This corresponded to the end of the nail at the metaphysial enlargement

of the shaft. In one animal there was also a stump of the distal branch ending about a centimetre above the fracture site. The cortex did not show in the adult the same amount of increased vascularity found in the young animal. The proliferation of vessels in the nailed bone was similar to that on the control side. Angiograms of transverse sections of the bone did not show the same striking appearance of vessels perforating the cortex as in the young animals, although a few of them were seen here also.

Histology—The extent of necrosis was roughly the same as in the young animals and involved from one-third to two-thirds of the inner cortex in cases in which no stump of the nutrient artery had remained perfusable—that is, in nearly every case. The changes were here much more limited and slower in appearing. At five weeks after the nailing the following was the main picture. Necrosis was spreading over the inner part of the cortex with the same characteristics as in the young animal. There was a thin layer of lamellated new bone formed all round the diaphysis. This was thin in comparison with that seen in young animals and even thinner on the proximal fragment than on the distal. In most of the diaphysis the marrow was necrotic and did not contain any vessels. Near the metaphysis giant cells containing lipoid were seen adjacent to living marrow. The fracture was uniting through a bridge established from the outer side which contained a little cartilage, but there was no callus as yet between the fragment ends. No endosteal callus was apparent. Two weeks later—that is, seven weeks after nailing—the picture had changed slightly. There was now some transformation mainly on the ulnar side of the cortex, where a few vessels had broken through the cortex into the canal. In some places a thin layer of new bone was found on the inner surface of the necrotic cortex. Very little bone marrow was present in the canal, but in some places its remnants looked like being transformed into new bone lamellae. A small amount of new bone was formed around the nail. The fracture had now united mainly through bone, but there was some cartilage on the outer surface of the callus. Even eight months after the nailing the picture had not substantially changed and there were still a few portions of necrotic cortex to be seen scattered about affecting the whole of the two inner thirds of the shaft (Fig. 33). On the proximal fragment the layer of new bone was still seen, as little transformation had taken place, particularly on the outer side. On the distal fragment, where the layer of new bone on the outer surface of the cortex was thicker, the greater part of the necrotic bone had been removed and partly replaced. It looked as if in these adult animals there were two types of behaviour in relation with the dead bone: 1) either the new bone was laid down slowly on both the inner and the outer surfaces of the dead bone, or 2) the dead bone was covered on its outer surface by new lamellae and was then removed from its inner surface.

DISCUSSION

Many investigators, among them Küntscher (1940, 1941), Greissmann and Reich (1944), Maatz (1951) and Silani and Amante (1949), have noticed the new bone formation at the diaphysis of nailed fractures, the experimental production of which has been described here. The explanations for this finding are varied. It has been considered the result of chemical or physical irritation from the material of the nail. It has also been ascribed to pressure of the nail against the bone, and to hormone diffusion from the marrow. Küntscher did not believe that these changes were the result of injury to the bone vessels, but some other authors, among them Silani and Amante (1949) and Marneffe (1951) suggested that the injury to the vessels might be responsible for the proliferation of the subperiosteal bone. One of the reasons why this problem has not been solved seems to be the insufficient knowledge of the role of the nutrient artery in the nutrition of the cortex. Even Marneffe (1951) has repeatedly stated that the nutrient artery contributes very little to the nutrition of the cortical bone of the rabbit. In a series of experiments we have found that, contrary to the current opinion, the nutrient artery is responsible for the nutrition of the greater part of the cortex. This is in agreement with the findings of a few early investigators such as Johnson (1927)

and others. It is quite reasonable, then, to expect that the changes we have mentioned will be produced when a large foreign body is forcibly introduced with considerable violence along the length of the marrow canal. Even if part of the nutrient artery could escape damage numerous branches would be destroyed and consequently a great part of the diaphysis would be deprived of its nourishment. It is to be noted that in rabbits, in which the progress of bone healing is rapid, large parts of the necrotic cortex persist eight months after medullary nailing.

Although this paper does not deal with nailing in man the results of the investigation might be of some help in the interpretation of the behaviour of human bone after Küntscher nailing.

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THE USE OF MYO-ELECTRIC CURRENTS IN THE OPERATION OF PROSTHESES

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In patients who have lost part of the upper limb automatic reactions which have become patterned in the central nervous system over a period of years are not lost, but continue to be used in relation to the phantom limb. For example, a patient told to grasp with the phantom will fire off from the nervous system the complete set of impulses to prime movers and synergists which have been integrated by continued use into the pattern which in his sensorium stands for "grasp."

It has long been known that electrodes placed suitably on the skin over a contracting muscle can pick up electrical changes which vary from a few microvolts to a few hundred microvolts according to the force of contraction. It was therefore considered that it should be possible to use these potentials from the muscle bellies in the stump or one of the synergists

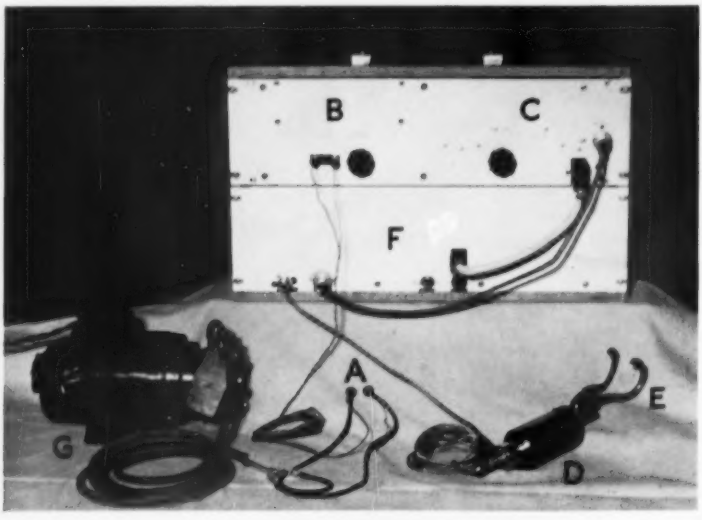

Fig. 1
The final apparatus.

to operate a prosthesis. The great advantage of such a system would be that the prosthesis would be directly controlled by the patient's cerebral cortex and no re-education would be required in the pattern of his muscular activity. This paper reports a preliminary investigation into the problem.

APPARATUS

We decided in the first place to restrict our aim to the construction of an apparatus capable of performing a simple open and close action when the subject made a light grasp with the fingers, and to concentrate on achieving reliability of action rather than complexity

of movement or feats of strength. We also decided to give no attention to reducing the bulk of the apparatus, and standard components were used throughout.

The apparatus which we evolved is shown in Figures 1 and 2. The fluctuations of potential appear on the surface of the skin and are picked up by the electrodes (A). These are small brass cups which can be held to the skin by suction through a side tube. Leads are taken to the balanced amplifier (B) which is similar in many respects to those used in electrocardiography and electromyography. After amplification the signal is taken to the discriminator (C) which when operated switches power through to the solenoid (D). This is

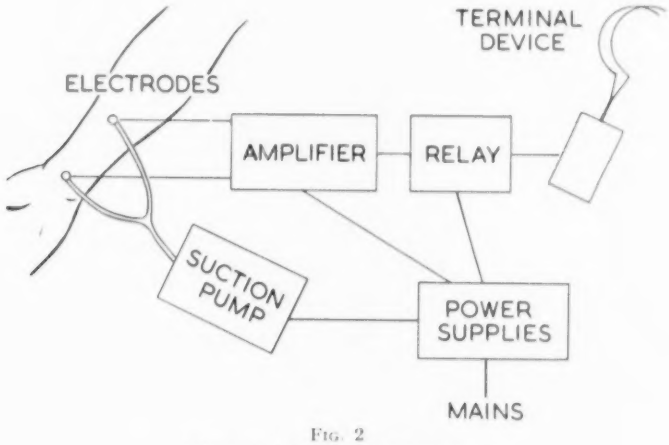

FIG. 2
Schematic diagram of the apparatus.

similar to an automobile " trafficator " and closes the split hook (E). The remaining apparatus consists of an electrical supply (F) connected to the mains, and a suction pump (G) for the electrodes.

As was expected, several difficulties were encountered in the design of the apparatus.

Thus electrical interference from the mains wiring and from electrical machines nearby was picked up by the subject and had to be reduced to a level well below that of the signal. This was achieved by the use of a balanced input in the amplifier and careful earthing of the subject.

Random electrical fluctuations in the amplifier itself and at the electrode-to-skin contact were reduced to a minimum by restricting the frequency range to which the amplifier responded. The most favourable range was found to be 100–1,000 c/s. Care was taken to ensure a good contact at the skin surface by cleaning with spirit and by the use of saline jelly under the electrodes.

Unwanted signals from muscles adjacent to the one selected to operate the device were reduced by careful placing of the electrodes in the optimum position, as found empirically.

It was found to be advantageous to introduce some " backlash " into the closing and opening of the switch (Fig. 3)—that is to say, to arrange that the signal required to close it was bigger than that at which it opened. In this way the strong contraction required for reliable closure of the terminal device could be considerably relaxed while the grasp was maintained, and the subject was not therefore required to maintain any excessive effort. The opening level was made considerably higher than the spurious signal level so that no difficulty was encountered in releasing the grasp when the contraction was relaxed.

Previous experiments had shown that the initiation of natural movements of the fingers

always gives a large burst of signals which later dies down to a steady level as the contraction is maintained (Fig. 4). This may be due to the extra initial force required to overcome the inertia of the limb, and it has not yet been established whether this initial burst is produced by amputees.

Finally, it was found that the suction electrodes and commonly used saline pads were unsatisfactory for normal operation over long periods because the electrode jelly dried. Chlorided silver cups which are sealed to the skin with collodion were found to be quite satisfactory and can be worn comfortably for many hours.

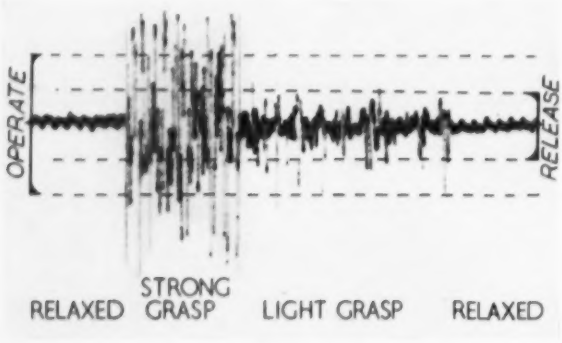

FIG. 3

Recording illustrating level of signal corresponding to different strengths of contraction.

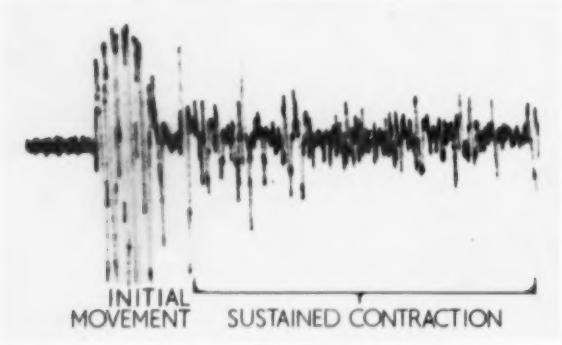

FIG. 4

Recording showing the "burst" of activity occurring on the initiation of a movement.

RESULTS

The apparatus described was tested on several normal subjects and was found to satisfy all the original conditions very well. It was sensitive enough to close, and remain closed, when a pencil was gripped lightly in the fingers, irrespective of movements of the wrist or arm. Similarly it was found that on relaxation the device opened immediately and remained open regardless of other movements not involving gripping with the fingers. This means that signals from other muscles than the required one had been successfully eliminated.

Rapid alternate contraction and relaxation of the finger flexors was followed faithfully by the device up to the speed of about three per second.

Most encouraging was the insensitivity of the apparatus to electrical machines working in the neighbourhood on the same mains supply. Commutator motors were run within two or three feet of the machine without any effect on its performance.

Obviously to operate the device it is best to pick up the changes in potential from one of the prime movers in the movement concerned, but experiments showed that if such were not available one of the synergists could be used provided it was not concerned in efforts directly antagonistic to the desired movement. In the latter case once grasp is achieved by the machine it is impossible to relax it, for in such efforts the synergist takes over the role of antagonist and the impulses continue to flow into the apparatus. A study of the movements of grasping with the whole hand or pinching between the finger and thumb disclosed that in both cases the flexor pollicis longus was the best muscle to use as a prime mover; of the synergists the brachioradialis was found most suitable.

Experiments on amputees showed that the pattern of use of muscles in this movement was persistent even after a period of years, although the best results were obtained when the amputation was recent.

DISCUSSION

An immediate possibility is the application of a pneumatic, rather than electric, drive to the terminal device. This would be more convenient in that it would avoid electrical interference at the very sensitive input connections which must be very close to the terminal device.

Having established that actions can be carried out reliably by myo-electric apparatus we had to consider whether such an apparatus could be made to give a graded response.

We believe this to be possible by the use of electro-mechanical servo-mechanisms, though the best system to use is not yet clear to us. There are many types of servo system common in electrical engineering, none of which compares in principle or subtlety with the human motor system. One way in which a graded grip might be obtained would be by means of a position control servo in which the position, or degree of closure, of the terminal device would be proportional to the strength of the muscular contraction. Such a device, if prevented from closing by the presence of an object between the claws, could be made to exert a force also depending on the strength of the contraction. This system would have two defects: in order to maintain the device closed a continuous strong grasp would be required; and the contraction required to exert a certain force would be dependent on the position of the claw.

A more perfect system from the mechanical point of view would be a velocity control servo, in which the velocity of the terminal device would be dependent on the signal. As in the position control servo the force exerted would also depend on the contraction. But unlike the position control servo no contraction need be made to keep the terminal device closed and motionless. Neither would the force exerted be dependent on the position of the claws. From a practical point of view, however, this system would suffer from the disadvantage that two signals would be required to control opening and closing speeds. These could be obtained only from a pair of muscles producing opposite movements, such as a flexor and extensor; but since one of this pair might also be used for the stabilisation of other joints the signal from it would be unreliable for operating an open and close device. Only in a prosthesis designed to carry out a large number of independent motions in a manner similar to that of the normal motor system would such a servo system be important.

The possibility of using signals from more muscles to perform more complex actions cannot be ignored, but would depend largely on the degree to which the apparatus can be reduced in size and complexity.

The sensory impressions from the skin and other tissues of the part that has been lost are, of course, missing in the amputee. Nevertheless it is conceivable that a "feedback" proportionate to the pressure exerted by the claw of a prosthesis could be used to stimulate an area of skin on the stump, and in this way a new conditioned response in the sensorium might be rapidly developed in the intelligent patient. This, in contradistinction to the movement of the claw, would need re-education.

There remains the problem of the child born without hands. Here, of course, the conditions are very different from those of the ordinary amputee who has developed in the years preceding amputation a pattern of hand consciousness and movement which can be used in relation to the prosthesis. The child born without hands can never develop a hand consciousness. But it is possible, provided there was no central nervous system deformity or agenesis, that such a child might develop in relation to a prosthesis a pattern similar to that which the ordinary person develops in relation to the hand if the process were begun early enough. Admittedly such a pattern would be a mere travesty of the wonderfully co-ordinated normal "hand consciousness," but it might be sufficient to enable such individuals to develop considerable skill.

CONCLUSION

Obviously these and other problems need much research, but the preliminary work already done is promising enough to indicate that a useful and dependable prosthesis could be developed to operate by the use of changes of muscle potential, and that such apparatus could be made light enough for practical use at the work-bench and in the home.

PROCEEDINGS AND REPORTS OF UNIVERSITIES COLLEGES, COUNCILS AND ASSOCIATIONS

GREAT BRITAIN AND FRANCE

BRITISH ORTHOPAEDIC ASSOCIATION

COMBINED MEETING WITH THE FRENCH ASSOCIATION OF ORTHOPAEDICS AND TRAUMATOLOGY

On May 5–7 members of the British Orthopaedic Association visited Paris for a combined meeting with the Société Francaise d'Orthopédie et de Traumatologie, under the chairmanship of their respective presidents, Professor Bryan McFarland and Professor P. Padovani.

On the morning of May 5 operating sessions took place at the following hospitals: Centre Médico-Chirurgical Foch (Professor P. Padovani), Cochin (Professor R. Merle d'Aubigné), Trousseau (Dr P. L. Chigot), Enfants Malades (Professor M. Fèvre), Saint Louis (Dr J. Cauchoix, Dr P. Lance), Clinique Desaix (Dr R. Judet) and Hopital Raymond Poincaré (Dr Pierre Gérard Marchant).

Surgery of the Paralysed Lower Limb

Equalisation of limb length—*Mr R. I. Stirling* (Edinburgh) said that when shortening of the longer thigh was indicated he preferred a long oblique osteotomy of the mid-shaft of the femur, fixed by transverse screws after the necessary overlap. Union was certain, which it was not after transverse resections, and he disliked the subtrochanteric operations for fear of damage to the blood supply of the epiphysial region and later osteoarthritis. Stapling of the epiphyses was uncertain, and in any case would not cause more than an inch of shortening. In the tibia he used a Z-resection; an inch and a half of shortening was the limit acceptable at one operation, but it could be repeated later. The calf muscles were sometimes slow to recover, and a raised heel for a while was helpful.

In bone lengthening operations the points of counter-pressure should be in the bone itself and not beyond a joint for fear of overstretching the ligaments. Equally one must beware of damaging a joint surface by undue pressure. He used four pins in the same bone, and in the case of the femur took care to distract the knee first. He used a Z-osteotomy in both femur and tibia, and stressed the importance of complete division of periosteum and fascia. In the case of the tibia there was grave danger that the lower end of the fibula might lag behind, rendering the ankle joint unstable, and he therefore preferred now to fuse the lower end of the diaphysis of the fibula to that of the tibia, particularly if the lower end of the fibula already lay unduly high.

A poor circulation in the limb was no contraindication to bone lengthening. The best age was eleven to thirteen, but it could be done earlier if the difference in length was not altering, or in a completely flail limb. Over the age of sixteen union was much slower. In cases of partial paralysis bone lengthening operations often altered the muscle balance, so that they should precede any stabilisation or tendon transplant operations. If the muscles were already balanced, it was usually better to shorten the other limb.

In 120 cases he had had only four of interference with the peripheral circulation and all recovered; but an increase of more than an eighth of an inch a day should not be attempted. The incidence of subsequent arthritis had not been significant, and any distortion of the foot was usually easily correctible by manipulation.

Paralytic lesions of the hip with particular reference to dislocation—*Mr G. Blundell Jones* (Exeter) said that the inherent stability of the hip could be spoilt by contractures or by alterations of the bony contours. Paralysis led to coxa valga, and coxa valga was a potent cause of dislocation. Pelvic obliquity might be due to contractures of either hip or trunk. With regard to corrective procedures, he thought that it was probably impossible to replace the hip abductors by tendon transplant; Mustard's ilio-psoas transplant was the most effective method. Osteotomy of the base of the femoral neck fixed with a Capener plate was satisfactory for marked coxa valga, and not only in paralytic cases. In spastic cases preliminary tenotomies and occasionally shortening of the femoral shaft might be required. He remarked that the onset of paralysis after the age of two might lead to coxa valga but rarely to dislocation; the latter was almost always the result of poliomyelitis in infancy. Shelf operations or arthrodesis were rarely indicated. In planning treatment the degree of coxa valga and rotational deformity, and the condition of the acetabulum all needed assessing; if arthrodesis was required he thought the Charnley central dislocation procedure was the best.

The value of tendon transposition in the buttock and thigh—*Mr J. M. P. Clark* (Leeds) thought that the revulsion that followed the first enthusiasm with which the work of Robert Jones and Tubby was greeted was now on the wane. It was important to realise that it was impossible to replace a completely paralysed muscle, that no muscle training will ever alter muscle imbalance, and that deformities may recur even after arthrodeses. Tendon transposition was best done to prevent deformity, and transplants needed protection for at least six months after operation.

Replacement of hip abductors was most difficult. The ilio-psoas transplant was satisfactory if a normal gluteus maximus and sartorius were present, but it was a severe operation. In the presence of a good gluteus maximus, shifting of the origin of tensor fasciae latae backwards could help a weak gluteus medius.

In adduction deformity tenotomy, neurectomy, and osteotomy all had a place. In preventing recurrence of the deformity he had successfully tried a new procedure in which the adductor origin, detached from the pubis and mobilised with nerve supply intact, was transposed under the rectus femoris and attached to the ilio-tibial band.

In the case of the knee, transplants into the quadriceps could be done 1) to prevent buckling, 2) to enable a caliper to be discarded, and 3) to prevent flexion deformity of the knee. They were most effective when the foot was stable, when any knee deformity had been corrected, and in the presence of strong hamstrings and at least fair glutei. Semitendinosus and gracilis medially, and biceps laterally, were all used, but semimembranosus must be left intact. He stressed the importance of the normal coupled action of the hamstrings with the knee extensors in the last part of the movement of straightening hip and knee, which therefore made the transplant a good one. The use of sartorius and tensor fasciae latae had not been satisfactory.

The principles of tendon transplantation in the prevention of deformities of the foot—*Mr D. M. Brooks* (London) said that the operations were easy, could be done early, and did no irremediable damage, but unfortunately at least one-third failed in their purpose. Equinus deformity could readily be controlled by appliances; calcaneus was uncontrollable but rarely crippling. An iron was less efficient in controlling valgus and varus of the heel, and a tight tendo calcaneus aggravated both deformities. Pronation and supination of the forefoot both caused pain in the big toe region, and instruments were useless in their control.

One must know accurately the power of muscles and what the deforming muscles were, a matter difficult to assess before the age of five. It was useless to employ a muscle as a transplant whose automatic phase of function was at variance with that of the recipient; hence the futility of transplanting tibialis anterior to the calf. The essential principles were that full passive correction should be possible, the deforming force must be removed, and the paralysed muscle action must be replaced.

Transplants of the peronei to the calf in cases of calcaneo-cavus with or without valgus had failed in more than half of forty-nine cases. Transplanting extensor hallucis longus to the first metatarsal neck failed in twenty-four of thirty-nine cases of pronation of the forefoot, and in a similar proportion transposing peronei to the dorsum of the foot failed to improve plano-valgus. The most successful group was that of equino-varus deformities, where only nine out of twenty-two failed to give improvement, and six of these were due to the later disinsertion of the transplant from its new attachment. In all groups secondary deformity was not uncommon.

He concluded that in spite of the many failures tendon transposition was a useful mitigating procedure in carefully selected cases so long as the cause of the original deformity had been eradicated; he doubted whether it was ever worth shifting a muscle which was not itself causing the deformity.

Surgical measures for the relief of paralysis of the intrinsic muscles of the toes—*Mr T. T. Stamm* (London) recalled that the Lambrinudi procedure of multiple interphalangeal fusions transferred the activity of the flexors from the interphalangeal to the metatarso-phalangeal joints. When the operation was originally designed it was planned to attack the accompanying cavus deformity six months later, but this had proved unnecessary because successful toe fusions were found to cure the cavus also. For this operation to succeed there must be no fixed deformity of the metatarso-phalangeal joints. Bony fusion must be produced; fibrous ankylosis gave rise to pain. The insertion of axial Kirschner wires produced too many failures of bony fusion; he thought the best method was to tie the toes down to a Lambrinudi footplate and to leave the splint on for six weeks. The best position was slight flexion of the proximal and slight hyperextension of the distal joint.

If there was fixed extension of the metatarso-phalangeal joints multiple tendon transplants of the long flexors of the toes to the extensors was a better operation, but was contra-indicated if there was much fixed flexion of the proximal interphalangeal joints. The two procedures were complimentary and should not be looked on simply as alternatives for any given case. Failures

were due to choice of the wrong operation, faults in technique, and the occasional patient who would not oblige with bony fusion.

He considered the operation of transplanting the extensor tendons into the metatarsal necks a poor one; it was unsound physiologically because the timing of the automatic action of these muscles was wrong for the new function required of them, and in any case the tendons seemed to return by magic to their original insertions.

In the subsequent discussion on these papers *Professor Ugo Camera* (Turin) showed some examples from his album of experience with leg shortening. *Dr P. Lance* (Paris) discussed the anatomical changes to be found in cases of paralytic dislocation of the hip, and *Mr H. J. Seddon* (London) stressed the need for independent assessment of a surgeon's results from tendon transplants in the foot; the basic idea was good, but fewer cases than we thought were in reality worth operating on. *Professor K. E. Kallio* (Helsinki) showed a film of his operation for arthroplasty of the hip using a cap of skin taken from the abdomen to cover the femoral head.

Osteochondritis of the Hip

An experimental study—*Dr J. Lemoine* (Paris) presented the results of a study undertaken with *Dr R. Lagrange* (Paris), largely at Oxford. He reviewed the various theories on etiology and described the normal vascular anatomy of the upper end of the rabbit's femur at various ages. They had operated on sixty rabbits between two and three weeks old. Ligature of the anterior circumflex vessels was found to produce only minimal changes, but ligature of the round ligament was followed by varying degrees of enlargement of the femoral head, with flattening, increased radiological density, and often some subluxation. Angiograms showed an increased vascularity of the head. The neck of the femur often thickened, and both macroscopically and microscopically the changes were very similar to those seen in Perthes' disease.

Clinical review—*Professor M. Fevre* (Paris) reviewed a series of cases of Perthes' disease, 80 per cent of which had occurred in boys. The age ranged from four to thirteen years, with greatest incidence between four and seven years. He had not found trauma or infection elsewhere to be important antecedents. Pre-existing coxa valga was rarely found. He divided the cases into two groups, depending on whether the changes began in the top of the femoral head or around the margins of the epiphysis. The former he ascribed to interference with the blood supply through the round ligament, the latter with the supply from the circumflex vessels; primary acetabular change might also occur. He showed an extensive series of radiographs to demonstrate the types proposed.

Osteochondritis in congenital dislocation of the hip—*Dr P. Petit* (Paris) had observed twenty-three cases among eighty-seven hips, but an incidence as high as 50 per cent had been reported. He had not seen the normal side affected. It was impossible to assess the prognosis during the first year of life: in some of the earliest cases there had been complete disappearance of the femoral head. Ten out of eleven infants under the age of one year treated by manipulative reduction and fixation in the Lorenz position were complicated by osteochondritis. He reviewed the possible causes of the condition, and considered that the important factors were 1) forcible reduction, 2) too powerful traction (the condition is commoner in high dislocations) and, above all, 3) pressure on the femoral head with poor articular contact and torsion of the capsule and its vessels from fixation in extreme positions. The younger the patient the greater the danger of osteochondritis; the femoral heads of older patients appeared to be more resistant. All cases were due to therapeutic causes, and he recommended reduction by gradual traction with fixation in not more than 60 degrees of abduction, moderate medial rotation and about 30 degrees of flexion.

Osteochondritis dissecans of the hip (Koenig's disease)—*Professor R. Guilleminet* (Lyons) described seven patients. Their ages varied from twelve to fifty-one, most occurring between eighteen and twenty-five. Five were male and two female. In most there had been no history of injury, the onset being gradual over about six to eighteen months. A few gave a history of sudden " catching " of the hip, but in most the symptoms and signs were those of an osteoarthritic hip. He had tried removing the affected area, which was always on the top of the head or slightly medial to it, and had even filled the resultant cavity with bone chips, but the results were poor. If conservative treatment failed, arthrodesis was the operation of choice, though one recently treated by arthroplasty was still satisfactory. Histologically the appearances were those of a sequestrum; except over the affected area the articular cartilage of the femoral head was normal. Differential diagnosis involved the exclusion of caisson disease, aseptic necrosis from other causes, and tuberculosis.

In discussion, *Sir Reginald Watson-Jones* (London) emphasised the importance of recognising Legge-Calvé-Perthes disease not as a " disease " at all but as a simple disorder from loss of blood

supply to the upper femoral epiphysis due to dislocation of the joint, fracture of the femoral neck, infection in the metaphysial region, or perhaps from metabolic disorder of renal or endocrine origin. It had been learned in recent years that with rest in bed for two or three years, though not necessarily with immobilisation in splints, frames or plaster, deformation and flattening of the femoral head could be prevented and a normally rounded contour be preserved. Of course it would not be known for another twenty years or so, until these patients had reached the age of thirty-five, whether late degenerative osteoarthritis had thus been avoided; but it seemed reasonable to assume that it might probably be so. Meanwhile, he asked, what harm did it do to insist on two or more years bed-rest in these children whose education could be continued in hospital or at home, in comparison with the forty or fifty years of disability that otherwise arises with such certainty.

Professor J. Trueta (Oxford) illustrated the histological and vascular changes to be seen in experimental osteochondritis in the rabbit. There was thickening of the epiphysial cartilage, and vessels could be seen penetrating vertically into the substance of the femoral head, particularly from the outer side. In the human subject there was no blood supply to the femoral head from the round ligament at the age of eighteen months; almost all came from the outer side. At the age of four vessels could first be seen entering the head from the round ligament. Only after fusion of the capital epiphysis did anastomoses occur between these vessels and the major supply from the outer side. The latter also supplied the femoral neck; hence the associated changes in this region. After the age of sixteen the anastomosis with vessels from the round ligament was adequate and the danger of Perthes' disease past. It had been shown by arteriograms that extreme positions of the hip obstructed the circulation to the femoral head. *Mr A. H. C. Ratliff* (Edinburgh) gave the results in forty-nine cases of Perthes' disease followed for an average period of seventeen years. Apart from a few who received no treatment all had been treated by fixation on a frame. Assessed by a point system relating to pain, degree of activity, range of movement and radiographic appearance they showed eighteen good, nineteen fair, seven poor and five very poor results. Although 75 per cent of the total were still fully active and free from pain, only 38 per cent had good radiographic appearances. Of the nine untreated patients only one had a good hip. The most important factor affecting the prognosis was the state of ossification of the head; the younger the child the better the prognosis. The average age of onset in patients with good results was six, with fair results eight, with poor results nine, and with very poor results ten. Absence of fragmentation was of good prognostic significance. A good immediate result was likely to be maintained for at least twenty-five years, even though half of such cases had unsatisfactory radiographs. *Dr C. Casuccio* (Italy) said he preferred the term "osteochondrosis." He had done biopsies of capsule, cartilage and bone in eighteen cases. These showed fibrosis of the capsule, thickening of the cartilage and the formation of an irregular layer of vacuolated cartilage deep to it which in places had grown down or herniated into the cancellous bone. Islands of cartilage were to be found between necrotic bone trabeculae, an appearance like that seen in other osteochondroses. The findings resembled those found in experimental osteochondritis in rabbits. All cultures from the biopsy specimens had proved negative. In confirmation of Japanese work he had found similar changes to follow experimental wounding of the articular cartilage.

Other Papers

Stabilisation of the hip by central dislocation—*Mr John Charnley* (Manchester) reviewed his results. In about half the cases he had used a compression screw. The essence of the operation was that it produced a bony block to adduction. Fibrous union gave results just as satisfactory as bony union because the bony block protected the fibrous tissue from being stretched during weight-bearing. A few patients had slight pain for the first few steps taken after long sitting. About 15 per cent of those with primary fibrous union progressed spontaneously to bony union after a year or so. Of 158 patients operated upon, he had assessed the results in 105 followed for one to six years after operation. There had been no mortality. There were two cases of sepsis which had not interfered with the final result, and one fracture of the neck of the femur at operation due to a technical error. Five per cent had developed later fatigue fractures of the femoral neck, but in three this was only noticed on routine radiographic examination. Five patients required later osteotomy for malposition, usually residual fixed medial rotation. There was no case of knee stiffness. The patients were in hospital for an average of eight weeks and no physiotherapy was required after their return home. They improved with time. He assessed the results as excellent or good in 88 per cent, and fair or unchanged in 12 per cent; none was worse. About half had fibrous union, and thirty-five patients had frank movement; the freer the movement the less satisfactory the result. *Professor Ugo Camera* (Turin) described his procedure for correcting lateral

rotation of the early osteoarthritic hip by transposing the greater trochanter and its attached muscles to the back of the base of the femoral neck. He remodelled the femoral head if necessary and in some cases he also brought down the outer part of the acetabulum. Pain and gait were said to be much improved.

Dr J. Debèyre (Paris) reported thirty-four cases of the central dislocation operation with good results although only four patients had bony union. Eighteen could walk without a stick.

Pain in the arm of cervical origin—*Mr H. Osmond-Clarke* (London) ascribed such pain chiefly to lateral disc lesions or degenerative arthritic changes involving the intervertebral foramina. Acute central disc prolapse affecting the cord was rare, but it called for urgent operation. In most cases radiographs could localise the lesions; myelograms were occasionally helpful but were usually only used when lumbar puncture showed a high protein level in the cerebro-spinal fluid, or as a preliminary to operation. It was now realised that cord involvement from the fibro-cartilaginous bar arising in association with chronic osteoarthritis was not uncommon. Oblique views displayed the intervertebral foramina; osteophytes arising from the inter-articular joints or joints of Luschka might press on the roots or interfere with their local blood supply. Patients were often found to have a coincident supraspinatus tendinitis or tennis elbow. Heat and stretching cured the great majority; manipulation should be used only in the milder cases—cord involvement had occasionally been precipitated when osteoarthritic changes were severe. The use of some form of plastic collar was helpful in the more chronic cases.

Operation was indicated in only 2 per cent of patients. Cases in which a collar had afforded good relief but in which pain recurred immediately after its removal required fusion, and if cord or severe neurological signs were present decompression by laminectomy and unroofing of the nerve roots, followed by fusion, was indicated. The operation required the cooperation of an orthopaedic surgeon and neurosurgeon. He demonstrated an impressive example in which he had fused the vertebral bodies through an anterior approach in a patient in whom a previous extensive laminectomy precluded the posterior route. He concluded by reiterating that not all pain in the area arises in the neck.

The treatment of radial club hand—*Dr D. C. Riordan* (New Orleans) showed an admirable film. Early correction of the deformity improved function and aided growth. He said that the presence of the Fanconi type of aplastic anaemia must always be excluded before treatment was considered, and remarked on the presence of ipsilateral lung aplasia in three of his seven cases. He reviewed the theories of etiology and the various operations that had been used in the past. The operation he employed was as follows: after correcting the deformity as far as possible by traction he excised the cartilaginous bar which was found running from the carpus to anything that remained of the radius. The carpus was then placed over the end of the ulna and maintained in position by a graft consisting of the upper end of the fibula taken complete with its epiphysis, the diaphysial portion being fused to the shaft of the ulna. The epiphysial line certainly remained intact for several years, but he had been unable to obtain convincing proof that growth had occurred. He remarked on the frequent association of limited flexion of the index finger in radial club hand, and had found that this was often improved after the operation described.

Arthroplasty in the late treatment of congenital dislocation of the hip—*Professor R. Merle d'Aubigné* (Paris) had done 129 arthroplasties in ninety-six patients, but felt that the indications for any form of arthroplasty should be restricted. Arthrodesis was the operation of choice in unilateral cases; only two of seventeen cases had been unsatisfactory. The Judet operation could give good results but they were too rare. In bilateral cases in which the lesion was asymmetrical an arthroplasty on the bad side had given poor results in half the cases because of subsequent deterioration in the other hip. Twelve out of sixteen bilateral arthroplasties had been satisfactory. Arthrodesis on the more painful side sometimes improved pain on the other side. Resection of the head and neck of the femur, as in the Girdlestone operation, had given a number of very good results, particularly in those who had had a previous osteotomy, and it was also useful when replacement arthroplasty had failed. After showing examples of the various groups he concluded by recommending arthrodesis for the unilateral case, and in bilateral cases fusion of the painful side with later arthroplasty or pseudarthrosis on the opposite side if necessary. If both sides were stiff and painful at the first examination, bilateral arthroplasty or resection of the head and neck was indicated.

Sacro-iliac tuberculosis—*Dr P. Gerard Marchant* (Paris) discussed the surgical treatment and results in eighty cases. There were two forms; a true arthritis and a juxta-articular type. Many cases of the first group had been reported which were not in fact tuberculous. The only proof lay in biopsy or positive culture from an associated abscess. Fusion was satisfactory in the purely articular type, but there was little point in fusing the joint in the para-articular type, or if there had been extensive destruction of bone, though it might well be worth while attacking the cavity surgically.

Fractures of the calcaneum—*Dr R. Judet* (Paris) said that the essential damage was that to the posterior articular surface and therefore to the subtalar joint. The depressed articular fragments could only be elevated surgically, but attempts made hitherto to maintain position by supporting them with grafts were inefficient and unsatisfactory, and depression recurred. Firm support could be obtained only by firmly squeezing up the crushed cancellous bone against the replaced articular fragments by lateral compression. This procedure he did through a lateral incision, the compression being maintained by a flat bone graft used as a large washer, through which he passed a screw to transfix the usually intact medial cortex of the calcaneum. Plaster fixation was required for only about eight or ten weeks, and he permitted weight-bearing after a few weeks. He showed a film of the operation which included an excellent end-result in a bilateral case.

The thanks of the British Orthopaedic Association are due in full measure to Professor Padovani and the members of the Société Francaise d'Orthopédie et de Traumatologie for their organisation of the meeting and for their generous hospitality, rounded off on the evening of May 6 by an excellent banquet at the restaurant " L'Orée du Bois."

ARRANGEMENTS FOR FUTURE MEETINGS OF THE BRITISH ORTHOPAEDIC ASSOCIATION

The autumn meeting of the British Orthopaedic Association will be held in Liverpool on October 6–8, 1955.

The 1956 spring meeting will be held at Gleneagles, Scotland, on May 3–5, 1956.

ROBERT JONES GOLF CUP

The annual golf competition for the Robert Jones Cup will be played over the links of the Royal Liverpool Golf Club at Hoylake on the afternoon of October 6, 1955. It is proposed to hold a dinner for golfing members in the Club House after the competition. Entries should be sent to Mr John V. Todd, 20 The Grove, Newcastle-on-Tyne, 3, who will be pleased to supply further details.

LIVERPOOL MEDICAL INSTITUTION

HUGH OWEN THOMAS MEMORIAL LECTURE, 1955

The Hugh Owen Thomas Memorial Lecture will be delivered on October 5, 1955, by Professor J. Trueta, whose subject will be " The Etiopathology of Osteoarthritis."

SCIENTIFIC SOCIETIES AND REGIONAL ORTHOPAEDIC CLUBS

THE BONE AND TOOTH SOCIETY

The Bone and Tooth Society held a symposium on " Repair Processes in Bones and Teeth " at the Institute of Orthopaedics, Royal National Orthopaedic Hospital, on March 24, 1955. Mr H. J. Seddon was in the chair.

Histology of bone grafts used in repair of bony deformities—*Professor W. D. Newcomb* showed a series of photomicrographs, mostly from material supplied by Sir Harold Gillies at Park Prewett Hospital. All the grafts died, but this did not mean that they failed. A graft was accepted by the body by being coated with new woven bone, a process depending on the formation of vascular granulation tissue by the host and prevented by sepsis. A rib graft removed after twenty-two days illustrated the three possible fates of bone: 1) being surrounded by new woven bone formed by osteoblasts; 2) being absorbed by osteoclasts; 3) remaining quiescent, being neither incorporated nor absorbed. Bone in pedicle grafts and in the anterior abdominal wall behaved in the same way as that in contact with living bone. Eventually the woven bone was removed and replaced by lamellar bone. This was illustrated by post-mortem specimens nine and fourteen months after grafting.

Repair of cancellous bone under high pressure—*Mr John Charnley* reviewed the evidence he had published for believing that, in the special instance of cancellous bone, mechanical compression actually stimulates osteogenesis and that compression arthrodesis of the knee does not owe its success to the fixation it produces. Knee-joints exposed to forces exceeding 80 lb. were absolutely solid four weeks after operation, but with forces of less than 60 lb. there was slight movement at four weeks (no " first intention " osseous union). In one special case the cut surfaces of the bones were shaped so as to render them unstable to flexion movements even when

under pressure. Biopsy after four weeks showed bony union, and the distribution of the new bone paralleled the distribution of pressure. With cortical bone, however, mechanical compression did not appear to have any noticeable effect in stimulating osteogenesis, but fixation was important, particularly if the bone was one that did not naturally generate profuse callus. Intimate contact could be effected just as adequately by light pressure as by heavy mechanical forces.

The repair of the periapical tissues after root canal therapy—*Mr A. H. R. Rowe* first illustrated the radiographic appearance of normal periapical tissues. Alterations in the normal architecture most commonly occurred after damage to the dental pulp by trauma or caries. The disturbance of the pulp might produce favourable or unfavourable reactions. The pulp might either eventually become calcified or die and cause damage to the periapical tissues. Periapical infection could be treated by periapical curettage, apicectomy, replantation or conservative methods. The speaker outlined the replantation technique which had been used by Mr R. E. Feaver and himself. In order completely to fill the root canals after sterilisation, a resorbable paste was employed as the root filling material, this being consolidated to prevent resorption down the root canal by a well-fitting gutta percha or silver point. Illustrations of complete or partial restoration of the normal periapical tissues were given. The technique was too recent for assessment.

Calcified repair tissue of teeth—*Mr E. P. Turner* said that the calcified components of a tooth had no potentiality for repair, but depended upon the cells of the adjacent connective tissue. Consequently repair of the enamel was found only in unerupted teeth in rare instances where an area of the crown had been resorbed and replaced by bone. Dentine and cementum were repaired by cells of the pulp or periodontal membrane, severity of injury influencing the structure of the resulting repair tissue. Odontoblasts laid down repair tissue after mild peripheral injury to dentine. A severe injury to the pulp, dentine or cementum could cause degeneration of the associated specialised cells and stimulate undifferentiated mesenchyme cells to develop into osteoblasts, which then laid down repair tissue resembling lacunar cementum or bone. Inclusion of rapidly degenerated odontoblasts in an amorphous calcified deposit might give the tissue a cellular appearance, but slow degeneration led to amorphous acellular repair tissue lacking distinctive architecture.

SOUTH-EAST METROPOLITAN REGIONAL ORTHOPAEDIC CLUB

A meeting of the club was held on March 12, 1955, at Orpington Hospital. Thirty-eight members and guests attended.

Treatment of hallux valgus—*Mr T. T. Stamm* showed several cases illustrating his recent work on the radical correction of hallux valgus, and he described his operative technique. The base of the proximal phalanx was excised and a piece of this bone was inserted as a wedge graft into the medial side of the base of the first metatarsal, to correct metatarsus primus varus. The adductor hallucis tendon was dissected from its attachments to the base of the proximal phalanx and the lateral sesamoid bone, and transplanted through a drill hole in the neck of the first metatarsal, to hold this bone in corrected alignment. Mobility at the metatarso-phalangeal joint was disappointing in some cases, but the shape of the foot was improved permanently and the patients were satisfied with the relief of pain.

Mr Austin Brown, for *Mr J. S. Batchelor*, showed a series of patients with hallux valgus treated by fusion of the first metatarso-phalangeal joint, internal fixation being achieved by a single screw passed through the proximal shaft of the phalanx into the metatarsal. Accurate alignment at the correct angle was essential. These patients rapidly achieved excellent painless function. Mr Batchelor had found the late results of Keller's operation rather poor, especially if there was deformity of the small toes.

In discussion *Mr Stamm* thought that further experience with these two operations would lead to a clarification of the indications for each. His own operative technique was proving useful in the younger patients for whom in the past one had felt that operation was contra-indicated. He had not yet found a satisfactory method of dealing with metatarsus primus varus in the adolescent without interfering with the metatarso-phalangeal joint. *Mr J. H. Mayer* supported the use of Keller's operation and emphasised that the results of the operation were greatly improved by the use of traction for several weeks after operation. He maintained traction in plaster for six weeks and was satisfied with the results obtained.

Treatment of claw toes—*Mr Stamm* described the treatment of claw toes. In his view only two operations had any place. When the main deformity consisted of fixed dorsiflexion at the metatarso-phalangeal joints he transplanted the flexor tendons into the extensor tendons over the proximal phalanges, with extensor tenotomy if necessary. When there was fixed flexion deformity of the interphalangeal joints he advocated arthrodesis of the interphalangeal joints by Lambrinudi's

method. *Mr R. C. F. Catterall* pointed out that neither of these operations was likely to succeed in the presence of motor neurone disease, and in such cases multiple toe amputations, though a mutilating operation, gave the best results.

Excision of the proximal row of the carpus—*Mr Stamm* showed a case of excision of the proximal row of the carpus for non-union of a fractured scaphoid. He had found this an excellent operation for this condition, and for Keinböck's disease and other disorders of the proximal row of the carpus. A good range of movement could always be restored in this way, and contrary to expectations degenerative arthritis did not supervene at the new joint. He had found that the grip was sometimes stronger than in the normal hand, and he attributed this to the conversion of a double link joint into a simple hinge with consequent increase in stability.

Hydro-cortisone—*Dr E. J. Crisp* described his experience in the use of hydro-cortisone for arthritis and soft-tissue lesions. In osteoarthritis of the knee it produced little if any benefit except in cases with minimal radiographic changes and symptoms provoked by recent trauma. Local injection of hydro-cortisone with hyalase was useful in rheumatoid arthritis, repeated at gradually increased intervals. For a wide variety of soft-tissue lesions, including tennis elbow, ligamentous strains, etc., he was able to produce excellent and almost immediate relief in the great majority of cases by injecting hydro-cortisone with hyalase and procaine. Results in frozen shoulder had also improved with the use of such injections locally at the time of manipulation under anaesthesia.

Pyogenic spondylitis—*Mr A. T. Fripp* showed a case of staphylococcal osteitis of the lumbar spine, starting after injury. The rapid course and the results of routine investigations suggested that this was a staphylococcal rather than a tuberculous lesion. The lesion was explored and curetted and staphylococcus pyogenes was cultured.

Slipped femoral epiphysis—*Mr J. S. Batchelor* showed several cases of slipped upper femoral epiphysis treated by open reduction and nail fixation. In a series of nine cases he reported eight good results. The other patient suffered avascular necrosis of the femoral head. Follow-up radiographs in all cases showed shortening of the femoral neck, but this did not interfere with function.

Congenital dislocation of the hip—*Mr Batchelor* showed a series of cases of intertrochanteric rotation and varus osteotomy for redislocation after the conservative treatment of congenital dislocation of the hip, done on the assumption that both the anteversion and the coxa valga predisposed to dislocation. In addition to correcting the anteversion he aimed to produce a marked degree of coxa vara. Serial radiographs of these hips showed remarkable correction of this coxa vara within two to three years of operation, and the results were good.

Other cases—Among the wide variety of other cases demonstrated a case of anterior lumbo-sacral fusion for spondylolisthesis gave rise to some discussion. *Mr Batchelor* preferred this method because it appeared to be mechanically sounder than posterior fusion and because a considerable proportion of posterior fusions failed to consolidate satisfactorily. *Mr J. H. Mayer* disagreed and maintained that with the use of cancellous bone chips applied to a carefully prepared posterior bed in which cancellous bone was exposed over a wide area of the laminae sound consolidation could be expected with confidence.

NORTH-EAST METROPOLITAN ORTHOPAEDIC CLUB

The North-East Metropolitan Orthopaedic Club was entertained at Whipps Cross Hospital, Leytonstone, by Mr H. A. Oatley on March 5, 1955. A clinical demonstration was followed by discussion of cases.

Clinical cases—*Mr G. Rigby-Jones* showed: 1) A series of slipped upper femoral epiphyses treated by open reduction and nail fixation. An interesting discussion followed upon the etiology of avascular necrosis of the femoral head. The speaker reported a case of rupture of the ligamentum teres found at open operation, and stressed the danger of manipulative reduction in unsuitable cases. 2) A case of poliomyelitis, with a dislocated painful hip on one side, and a flail hip on the other. 3) A case of arthrogryposis, in which both hips and one knee were dislocated. 4) A case of cervical scoliosis from chronic osteomyelitis of the cervical spine, with weakness of the right hand.

Mr Oatley showed the following. 1) A modification of Keller's operation, in which a capsular sling was passed round the medial aspect of the first metatarsal head, which had the effect of stabilising the great toe and overcoming the metatarsus primus varus. 2) A cure of congenital rotation and varus deformity of small toes, by the transplant of the long flexor tendon across the toes to the lateral sides. 3) A review of femoral neck fractures in which Smith-Petersen nailing had been unsuccessful. 4) A case of congenital absence of the tibia and of the medial femoral condyle, in which medial transplant of the fibula was contemplated. 5) A case of congenital absence of the fingers.

SOUTH-WEST ORTHOPAEDIC CLUB

The spring meeting of the South-West Orthopaedic Club was held at the Gloucester Royal Hospital on June 11, 1955. Twenty-eight members attended.

Amputations—*Mr R. Merryweather* discussed amputation stumps and the fitting of prostheses, based on impressions gained at a course at Roehampton. The ideal length of an above-knee stump was 10 inches, or 4 inches measured from the knee joint; the latter measurement was easier to make in fat people. Amputation through the knee was favoured, especially in elderly patients. The Stokes-Gritti and transcondylar amputations were not recommended because the patella might wander. The Symes amputation was now considered a good operation at Roehampton, but the classical amputation was preferred to the modified one because the heel flap in the latter might be pulled too far forward when the scar contracted. Mr Merryweather explained the features of the anatomical or suction socket, which was usually of wood. Suction sockets were not recommended for old patients or in cases of vascular disease.

When a prosthesis had to be fitted to a child, it must be provided as soon as possible and certainly by the time the child was five years old. Children always did well with artificial limbs. They could walk on the limbs as soon as they were provided and they never suffered from phantom limbs. The amputation stump should always be as long as possible and performed through a joint or through the epiphysis. In difficult cases of short lower extremities from congenital deformity prostheses employing the O'Connor principle could be supplied. At present, although still under consideration, the kinematisation of stumps had not proved satisfactory. The pectoral transplant was the only one used and it was not powerful enough to be as satisfactory as the sling-operated limb.

Scoliosis—*Mr W. Hedley Hall* reported the further progress of five patients with idiopathic scoliosis treated by stapling more than three years ago, whom he had previously shown to the Club. None of the patients had shown improvement in the curve. When only one staple was used between each pair of vertebrae the curve could increase. Staples had not been extruded or opened out. He felt that it was still too early to decide the value of this treatment. Certain technical improvements would be made in future. Two staples should be placed between adjacent vertebrae in order to control rotation. If staples were employed, they should be used early and he would advise their use in any curve kept under observation for six months and increasing. Severe scoliosis would not respond to this form of treatment because the growth possible on the concave side was not great enough to overcome extreme deformity.

Manipulation of the spine—*Mr J. Bourdillon* discussed the indications and principles for manipulation of the spine. Provided there was no evidence of infection or neoplastic disease he treated all cases of backache by manipulation. He had been dissatisfied with the results of laminectomy. He had been impressed by the manner in which patients had lost their symptoms after manipulation without anaesthesia and said that in some instances the pain could be relieved as if by " turning off a switch." His interest had been further stimulated by seeing an osteopath at work. To be successful without anaesthesia definite joints at fault in the spine should be manipulated and not the whole spine. This was effected by locking the other joints of the spine by positioning the patient properly. An essential of the procedure was that it should not cause pain. He felt that most pain in the back came from zygapophysial joints, which became stiff and interfered with the mobility of the disc and therefore with their nutrition. He disagreed with those who said there was no movement in the sacro-iliac joints. It was mobile and was able to produce low back pain even in women who had not been pregnant. He showed how he decided clinically whether there was any sacro-iliac displacement. He believed that sacro-iliac displacement could produce pain on the medial side of the knee simulating a cartilage injury and in some instances could lead to a painful heel. He also felt that some cases of tennis elbow were due to displacement at the cervico-thoracic junction. Frozen shoulders in the early stages could be due to trouble in this region, and could be relieved by manipulation. Pain in the tempero-mandibular joint was sometimes produced by stiffness in the atlanto-axial joint. There was no doubt that dizziness and migraine and some cases of headache occurred as a result of stiffness in the neck and could be relieved by manipulation. He demonstrated on a living model the various " holds " he employed in manipulating the sacro-iliac joints and the thoracic and cervical spine.

In discussion *Mr H. Keith Lucas* said that there was an increasing belief that girdle pain, tennis elbow, frozen shoulder and painful heels could be arising from a central source possibly due to upset sympathetic function. Campbell at Bristol had shown that blocking the sympathetic nerves could relieve pain in the face and neck. Ophthalmic surgeons had noticed changes in the cervical spine in cases of iridocyclitis. He was not in agreement with Mr Bourdillon over sacro-iliac mobility. He considered that there was no movement in the sacro-iliac joint and Mr Bourdillon's methods did not demonstrate that he was manipulating this joint alone; in fact it seemed that the joints between the fourth and fifth lumbar vertebrae were being manipulated rather than the

sacro-iliac joints. *Mr R. F. Winckworth* believed that the sacro-iliac joint was mobile and that it moved in extension. *Mr E. Mervyn Evans* pointed out that manipulation of the spine had been practised for a long time and that his late chief, Mr Blundell Bankart, wrote a book about the subject. In his practice he had been struck by the success of the unqualified practitioner in manipulating patients with signs of root pressure. He felt that the essential qualities of the manipulator were that he should be over six feet, strong, and fairly heavy. *Mr F. C. Durbin* believed that two other characteristics which the manipulator should possess were a strong personality and "good sales talk." He also felt that in a great number of cases of backache it was difficult to discount a functional element which was often relieved by several visits for treatment. Replying, *Mr Bourdillon* said that patients required from two to six manipulations at weekly intervals. If patients required more than this number of treatments, he suspected that they liked coming for treatment and on this account he usually discontinued it.

Tibialis posterior syndrome—*Mr A. W. Fowler* described the tibialis posterior syndrome, or chronic synovitis of the tibialis posterior sheath at the medial malleolus. His experience was based on seven cases. The condition was seldom diagnosed early and it was often mistaken for osteoarthritis of the ankle and treated conservatively without relief. There was swelling behind the medial malleolus with tenderness, but movement at the ankle and foot was usually full. At operation the tendon sheath was found to be swollen and thickened and the tibialis posterior tendon was greatly enlarged. The inflamed synovium was excised, with relief in all cases. He believed from the histological findings that the changes in the synovium were like those found in chronic villo-nodular synovitis.

Tuberculosis and rheumatoid arthritis—*Mr H. Keith Lucas* gave a further report on a patient shown to the club four years ago of rheumatoid arthritis and tuberculosis of the hip occurring together in a female patient. After treatment her condition had become quiescent and she obtained a job as a typist. In 1953 after domestic difficulties and a nervous breakdown she had an exacerbation of the swelling in her joints which subsided on rest. Six months later she developed a cold abscess in the buttock and radiographs revealed a typical tuberculous lesion affecting the fourth and fifth lumbar vertebrae.

Clinical cases—*Mr J. F. H. Stallman* showed several cases of displacement osteotomy for osteoarthritis of the hip with internal fixation with a triflanged nail. No post-operative immobilisation was employed except an abduction bar between the feet. He also showed one case of infantile coxa vara treated by subtrochanteric osteotomy and fixation with Steinman pins incorporated in a plaster spica. This child was a member of a family several of whom had been shown to have infantile coxa vara.

Mr Bourdillon showed the results in nine cases of slipped upper femoral epiphysis treated during the last five years. Seven had been treated by open reduction and Smith-Petersen nailing, and two had a manipulative reduction and Smith-Petersen nailing. There was no case of avascular necrosis. He also showed a case of old unreduced congenital dislocation of the hip in a child of eight, treated by reaming out the acetabulum and the insertion of a metal cup. The head of the femur later dislocated out of the cup; so the cup was removed and the head was replaced in the acetabulum. The cartilage of the head and acetabulum had regenerated after a year and the child now walks with a stable hip and has almost full range of movement.

Dr A. M. Jatoi showed a patient with multiple fibrocystic disease of bone due to a parathyroid adenoma. After an operation for removal of the adenoma she sustained a stress fracture of the neck of the right femur. This was nailed and healed rapidly and she had now a normal hip.

He also showed a case of Madelung's deformity of the right wrist in a boy of fifteen. The various operative procedures for this condition were discussed.

THE BIRTHDAY HONOURS

MR JOHN C. MENZIES

Orthopaedic surgeons all over the world will be delighted that Mr John C. Menzies, an Honorary Fellow of the British Orthopaedic Association, has been appointed O.B.E. in Her Majesty's Birthday Honours. Everyone who has had anything to do with the Robert Jones and Agnes Hunt Orthopaedic Hospital, and most especially the host of residents from every quarter of the globe, have acquired a regard and a friendship for John which must be quite unique among hospital superintendents. No one has done more to make "Oswestry" the outstanding centre that it is, and it is probably true that no layman for many years has done more for the benefit of orthopaedic surgery itself.

Menzies came to Oswestry in 1928 after being chief lay administrator to the Surrey Public Health Department. He took a major share in creating and extending the after-care clinic system,

which now spreads through eight counties and which has grown to deal with 20,000 new patients a year. The hospital and its clinics have had his untiring and complete devotion, a devotion which nearly cost him his life when, in the disastrous typhoid epidemic which struck Oswestry in 1948, he was one of the worst-hit patients among the survivors. Perhaps his greatest contribution to the hospital was made in that same year. Without his energy and foresight when half the buildings were destroyed by fire and 117 people were stricken with typhoid, it is highly unlikely that the magnificent new wards and departments would have risen from the ashes or, indeed, that the hospital could have continued at all. By most of us, however, John will always be remembered chiefly for the spirit of generosity which has been the hall-mark of the Oswestry Hospital as long as we have known it. In this age of the tidy-minded administrator, when uniformity has been valued above originality or tradition, he has saved for Oswestry the unique spirit given to the hospital by its founders. No honour has been better deserved.

JOHN C. MENZIES

IRELAND

IRISH ORTHOPAEDIC CLUB

A meeting was held at the Royal Victoria Hospital, Belfast, on April 2, 1955.

Experiences of bone bank—*Mr R. J. W. Withers* (Belfast) discussed the use of the bone bank in Belfast. Cadaveric boiled bone had been used in forty-two cases of different types. Generally speaking it had been valuable in spinal bone grafting, and also in Brittain's arthrodesis of the hip. It had not been so useful for non-union of the long bones. The main difficulty seemed to be that the cortical bone did not seem to perform any function other than as an internal splint. Cancellous bone, however, seemed to produce a satisfactory stimulus for bone growth.

He showed many of the cases and these provoked considerable discussion.

Problem of leg inequality—*Mr G. W. Baker* discussed the various possibilities of equalising leg lengths, and showed some interesting cases. These aroused considerable interest because many problems of leg inequality have arisen after epidemics of poliomyelitis in the past ten years.

Rupture of the collateral ligaments of the knee—*Mr R. I. Wilson* (Belfast) reviewed fifty-two cases. Many of the results of conservative treatment were unsatisfactory, and a plea was made that operative repair should be considered, especially in severe ligamentous tears.

Paraplegia—*Mr N. S. Martin* showed interesting examples of paraplegia from different causes, and discussed the relative values of different methods of operation in paraplegia complicating tuberculosis of the spine. He also showed a patient with cauda equina paralysis caused by a gross lumbar disc prolapse.

After the clinical discussions the visitors were conducted around the recently opened Institute of Medical Science by Professor H. W. Rodgers.

UNITED STATES OF AMERICA

RETIREMENT OF MISS FLORENCE L. DALAND AS ASSISTANT EDITOR TO THE AMERICAN BOARD OF ASSOCIATE EDITORS

At its last meeting the British Editorial Board learned with regret that within the next few months Miss Florence Daland will be retiring from her duty as Assistant Editor to the American Board of Associate Editors of the Journal, and noted with great satisfaction that she will be appointed a Consulting Editor to the American Board. During the last thirty years nearly every orthopaedic surgeon, not only in the United States but also in Britain and the Commonwealth, has known Miss Daland as a faithful, loyal, tireless and enthusiastic supporter of all that orthopaedic surgery means. We would quote just one word—it is the motto of the Armorial bearings of the British Orthopaedic Association *RECTE*; that means straightness of mind as well as straightness of limb. The British Editorial Board passed a formal vote of recognition of the great services of Miss Florence Daland, with warm-felt thanks for all that she has done for orthopaedic surgery and for the advancement of the *Journal of Bone and Joint Surgery*.

AUSTRALIA

BRITISH MEMORIAL FUND FELLOWSHIP IN POLIOMYELITIS RESEARCH

The British Memorial Fund, established in Victoria by public subscription, has offered a Fellowship with £1,000 (Australian) as a gesture of "loyalty, gratitude and affection" to the British people "in recognition of their role in saving civilisation in the second world war."

The Fellowship provides for ten months' study in Victoria for the selected candidate, and covers travelling and living expenses during the period. Accommodation will be arranged by the Fund. Wives and children are welcome but no extra expenses can be paid to cover them. The upper age limit for both men and women is thirty-five years and applicants must be of British stock of at least ten years' residence in the United Kingdom.

The Fellowship is to be granted to a medical practitioner whose duties associate him with Public Health work in the treatment and after-care of cases of poliomyelitis in the country districts of England, Scotland and Wales.

Full details can be obtained from The Honourable Sir John Lienhop, Agent-General for Victoria and Chairman of the British Memorial Fund, London Selection Committee, Victoria House, Melbourne Place, Strand, London, W.C. 2. The closing date for the receipt of applications is August 5, 1955.

BELGIUM

BELGIAN SOCIETY OF ORTHOPAEDICS AND THE SURGERY OF THE LOCOMOTOR SYSTEM

On April 22–23 the president, Professor Bryan McFarland, and some twenty members of the British Orthopaedic Association attended the spring meeting of the Belgian Society of Orthopaedics and the Surgery of the Locomotor System at Brussels at the invitation of the Society's President, Dr Robert Soeur.

A report on the functional results of arthroses was presented by Dr de Racker and was widely discussed, and papers on a variety of subjects were read by Belgian members and the visitors. The social programme was equally full and enjoyable and gave further demonstration of the hospitality for which our Belgian friends are so justly renowned.

INTERNATIONAL SOCIETIES

THIRD LATIN-AMERICAN CONGRESS ON ORTHOPAEDICS AND TRAUMATOLOGY

The third Latin-American Congress on Orthopaedics and Traumatology will be held in Mexico City from January 16–21, 1956, under the auspices of the Mexican Society of Orthopaedics and Traumatology. The organisers hope that many orthopaedic surgeons from abroad will be able to attend the conference. Communications should be addressed to Humboldt No. 63, Mexico D.F., Mexico.

Book Reviews

THE PAINFUL PHANTOM. Psychology, Physiology and Treatment. By Lawrence C. Kolb, M.D., Section of Psychiatry, Mayo Clinic, Rochester, Minnesota. $8\frac{1}{4} \times 5\frac{1}{2}$ in. Pp. 50. 1954. Springfield, Illinois: Charles C. Thomas, Publisher. Oxford: Blackwell Scientific Publications. Price 11s.

One would expect any publication from the Mayo Clinic to be well worth reading, and Dr Kolb's publication is no exception. Although the book is written mainly from the neuro-psychiatric angle it throws much light on the perplexing problem of the painful phantom of the amputee and points a way to forms of treatment that are being probed by informed observers in Great Britain.

Dr Kolb's findings that the small percentage of patients with persistent pain, for which no physical cause can be found, often have a background of failure to adapt to emotional, domestic, social or environmental difficulties, conforms with British opinion—the pain often being a psycho-somatic manifestation of an inherently unstable make-up, temporary or permanent. Early treatment, with a disentangling of the difficulties, will often prevent a more prolonged fixation. The horror of mutilation is very real, and prior contact with amputees, or even stories about them, may influence the behaviour of the individual who is unfortunate enought to lose a limb. This is probably most true of young adolescents who, after amputation, have a sense of failure to a physically strong and athletic father or a beauty-worshipping mother.

The booklet is excellently written; and the reasons given for the presence of a phantom, its persistence in some cases, why it is painful in others and recurs from time to time, are simple, acceptable and logical. Dr Kolb has noted current opinion on various puzzling aspects of the problem; and his ideas that each case is worthy of investigation by a team of experts, medical, surgical, orthopaedic, neuro-surgical and psychiatric, follows the pattern of thought in this country. That there is a place for electric convulsive therapy, suggestion, psycho-analysis or other forms of psycho-therapy is evident. There may even exceptionally be a place for leucotomy in long-standing and intractable cases, but it should always be remembered that leucotomy carries the risk of a deterioration in social behaviour and should not be undertaken without very serious thought.

This booklet should be read by all students of pain in general and of the problem of the painful phantom in particular. Dr Kolb is to be congratulated on throwing more light on a very puzzling problem.—T. Ritchie.

CONNECTIVE TISSUE IN HEALTH AND DISEASE. Edited by G. Asboe-Hansen, M.D., Connective Tissue Research Laboratory, University Institute of Medical Anatomy, Copenhagen; with twenty-two other contributors. $10 \times 6\frac{3}{4}$ in. Pp. 321, with 69 figures. 1954. Copenhagen: Ejnar Munksgaard. Price D. kr. 50.

The current and apparently widespread interest in the biological details of connective tissue is surely a singular chapter in the history of medicine. There seems to be a great demand for literature on this subject and if the lucubrations of its many proponents are properly absorbed the general body of doctors must be far better informed about it than they are about many other and more important aspects of pathology. A few moments' reflection will show that this extraordinary enthusiasm for connective tissue has developed largely by chance, from the coincidence of certain events in the world of medicine. Firstly, there was the trend of medical thought towards the problems of chronic senile diseases, such as arthritis, rheumatism and hypertension. Secondly, there was the rather mysterious appearance in significant numbers of such diseases as polyarteritis and disseminated lupus erythematosus. Then came Klemperer's concept of a family of collagen diseases, to include not only those diseases that Klinge grouped together as allergic because they exhibited a basic anatomical lesion of fibrinoid swelling of collagen, but also other diseases mainly incident upon the connective tissues but not patently allergic. The term "collagen disease" caught the public fancy, and remains a name readily grasped by those who perhaps little understand

its full meaning. Next came Hench's demonstration of the antirheumatic, or at least antiphlogistic, effects of the adrenocortical hormones, which stimulated a vast output of research, observation and speculation. Coming along to meet these strictly medical developments were new techniques nicely adapted for the occasion—histochemistry, the electron microscope, chemical identification of mucopolysaccharides, and the use of tracer elements in studying the metabolism of fixed tissue. It was therefore almost inevitable that a great deal of research and interest should now become centred on the connective tissues; and having, as it were, at last caught the ear of the larger medical universe, the basic researchers made the most of their opportunity.

The total gain in biological knowledge has been very great, but it is almost impossible to assess the strictly medical value of all this activity. Unfortunately it has not yet been possible to apply more than a fraction of our newly-won information directly to the practice of medicine, although many new and somewhat elaborate theories of pathogenesis have been constructed. Nothing but good, of course, can come from all this delving into a long neglected realm of physiology and pathology, but its immediate usefulness to the practising surgeon or physician should not be exaggerated. In this respect, some of the contributors to this volume, and above all its publisher in his blurb, tend to over-enthusiasm. Otherwise the book is admirable and perhaps the best presentation of the subject for the general medical reader that the reviewer has yet encountered. It is altogether better, more readable and more understandable than the symposia and conference reports on the same topic that have recently appeared. There are twenty-two chapters, by twenty-three authors, fourteen from U.S.A., seven from Scandinavia, and one each from Italy and England. Some of the chapters are authoritative and particularly helpful to the non-specialist, like those by Karl Meyer on the chemistry of the ground substance, and by F. Duran-Reynals on the spreading reaction. The chapters specifically dealing with clinical groups of diseases tend to be too synoptic. Klemperer's chapter reviewing the present status of his concept of collagen diseases should help to clear up many misunderstandings, but it is hard to hope that any scheme of "intercellular pathology," to which he looks forward, will bear even a tenth of the fruit that has been borne by "cellular pathology" in its hundred years of undecaying life.

The book is a useful one which may claim the attention of anyone who is engaged on researches involving connective-tissue behaviour and disease. It is up to date and covers most of the ground adequately, and each chapter has a useful, though sometimes rather personal, list of references. —Douglas H. Collins.

ALESSANDRO CODIVILLA e VITTORIO PUTTI nel ricordo di un loro contemporaneo. By Augusto Anzoletti. $8\frac{1}{2} \times 6\frac{1}{2}$ in. Pp. 133, with 11 figures. 1954. Bologna: Cappelli Editore. Price L. 1,500.

This is a most fascinating little book. It really should be translated into English because of the interest which lies in the influence of the Italian School on the British at the beginning of this century. The book is in no way scientific, but it contains intriguing little human pictures of the two great Masters named in the title. Innumerable little personal anecdotes, incidents and episodes of Codivilla and Putti and their assistants cover the period from 1896 to 1940. The importance rests in the way the book brings vividly to life these two men whose work built the Rizzoli Institute and so laid a large part of the foundations of orthopaedic surgery: the development of the Institute is indicated and so is traced the progress of orthopaedic surgery from a neglected backwater to its present powerful position in full flood. But the main interest is perhaps the intensely human portraits of Codivilla and Putti as they emerge from these pages—Codivilla modest, logical, cold and practical, going about his hospital, frequently in pain from an abdominal disorder, and struggling with financial difficulties and primitive surgical facilities. Putti of much wider interests and mind, a scholar, a bibliophile, proud if not arrogant, impatient of objections, a dictator in an age of dictators, "handsome like a great Italian of the Renaissance"—as Leriche had to say—he appeared

Alessandro Codivilla

to the people as a prince, as a king. To those who remember Putti this picture will ring very true.

These were personalities unlikely to be too easily satisfied, and this generation is heavily in debt to their dissatisfaction.—Bryan McFarland.

V. Putti e il P. Abate Procuratore degli Olivetani Don Placido Lugano (1936)

SCURVY AS A SKELETAL DISEASE. By H. J. Van Wersch, M.D. 9½ × 7 in. Pp. xvi + 365, with 182 figures and 52 tables and two colour figures. 1954. Utrecht: Dekker & Van de Vegt N.V. Price $7.30.

Dr Van Wersch, having correctly diagnosed a prolonged illness seen in general practice as scurvy and cured the patient, devoted several years to a scientific study of the disease, concentrating upon the skeletal manifestations and contrasting them with those of experimental rickets. In scurvy he explains certain observations—scarcity of osteoblasts and diminished alkaline phosphatase activity, and the changes in the cartilage cells of the proliferative zone (suppression of the hypertrophic cells and accumulation of glycogen in the others)—by presumptive blocking of the phosphorylase-phosphatase system and consequently a diminution in phosphate ions and glucose. The converse changes in rickets may be explained by stimulation of this enzyme system. The book, which is well translated and well illustrated, contains an interesting historical section, a bibliography and the results of clinical research on one patient, but is mainly concerned with experiments upon scorbutic guinea-pigs and rachitic rats. It is a record of much patient basic investigation rather than a source of great immediate clinical interest.—H. Jackson Burrows.

LE RHUMATISME. Études cliniques, biologiques et thérapeutiques. Edited by Professor F. Coste with twenty-nine other contributors. 3e Série. 9 × 6 in. Pp. 388, with 68 figures. 1955. Paris: Expansion Scientifique Française. Price 2500 fr.

This is not a text-book upon rheumatism but is a collection of papers on five subjects of interest to rheumatologists: osteoarthritis of the hip joint; gout; the role of virus infection in rheumatism; adrenal hormone therapy; cranial osteoporosis. Several papers are devoted to each subject. In the face of a spate of surgical writing the editor (Professor F. Coste) has felt it desirable to give special emphasis to the more conservative measures. Thus there are several papers devoted to physical therapy including hydrotherapy for osteoarthritis. One particular surgical paper, however, discusses the relief of pain in hip joint lesions by cordotomy. The procedure is not encouraged for a disease having no great threat to life, because five out of eight patients thus treated developed a most unpleasant sequel at varying periods after operation. This sequel was a recurrence of pain of distressing thalamic type. No satisfactory physiological explanation could be given. Upon gout the studies tend to upset the old tradition that it is due to a defect in the breakdown of nucleoproteins and purines within the body. Instead it is suggested that new purine bodies are synthesised in the body from normal food sources. This, however, does not appear to make much difference to the diagnostic or therapeutic problems. In the discussion upon adrenal cortical therapy there is a suggestion that the combination of chrysotherapy with cortisone has a valuable place. This is a very well produced book containing much that will stimulate the interest of the rheumatologist rather than the orthopaedic surgeon.—Norman Capener.

THE JOINTS OF THE EXTREMITIES. A Radiographic Study. By Raymond W. Lewis, M.D., Formerly Director, Department of Radiology, Consultant in Roentgenology, the Hospital for Special Surgery, New York. 11¼ × 9 in. Pp. vii + 108, with 102 figures. Index. 1955. Springfield, Illinois: Charles C. Thomas, Publisher. Oxford: Blackwell Scientific Publications. Price 61s.

The book provides a very short description of some radiological appearances that may be detected by methods not usually used in routine radiography.

No attempt has been made to supply a complete bibliography or a text-book description of x-ray diagnosis and only a few diseases are included in the text and illustrations. The material is obviously obtained from the collected experience of a radiologist who has devoted some time and thought to problems that are not readily solved by standard methods.

The value of soft-tissue radiography is usually neglected, but has been employed successfully by this author. The standard of illustrations is low, but most are accompanied by line drawings.

There are many useful hints on radiographic technique which can be used by junior and senior radiologists.—Campbell Golding.

LES ASPECTS NEUROLOGIQUES DES MALFORMATIONS CONGÉNITALES DE LA CHARNIÈRE CRANIO-RACHIDIENNE. By Raymond Garcin, Professeur agrégé à la Faculté Médecin de la Salpêtrière; and Doros Oeconomos, Ancien Interne des Hôpitaux de Paris, Chef de Clinique neuro-chirurgicale. 10 × 6½ in. Pp. 206, with 94 figures. Index. 1953. Paris: Masson & Cie. Price 2015 fr.

This monograph, which is one of a series on neurological subjects, deals fully with the problem of the nervous complications of congenital abnormalities of the upper part of the cervical spine and of the region of the foramen magnum. It is mainly concerned with basilar impression and with the Arnold-Chiari malformation, but it contains much information of value to anyone studying such lesions as congenital dislocation of the atlas and aplasia of the posterior arch of the same bone. There is a considerable bibliography and an adequate series of illustrations.—D. Ll. Griffiths.

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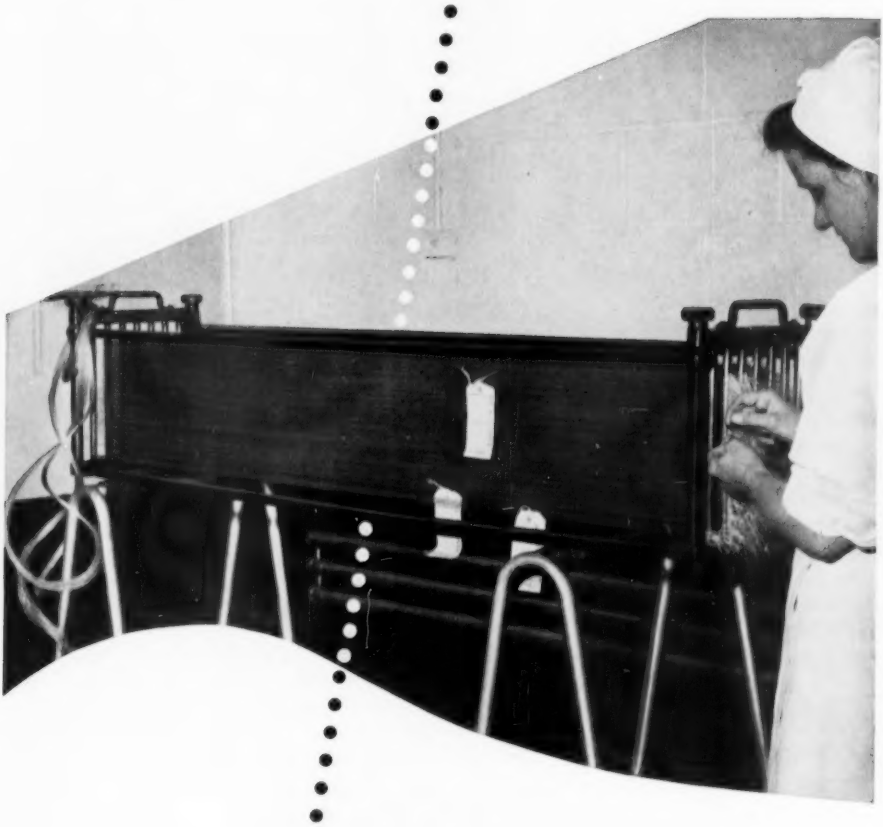

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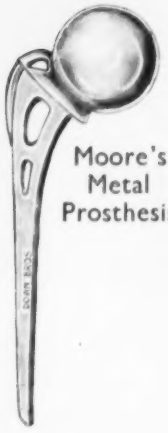

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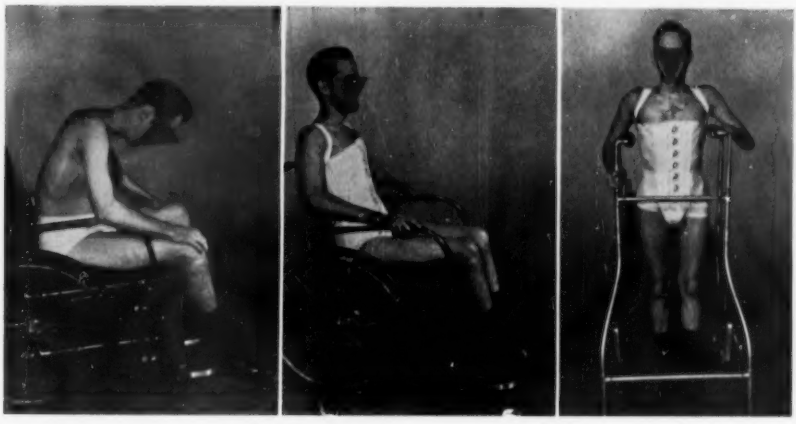

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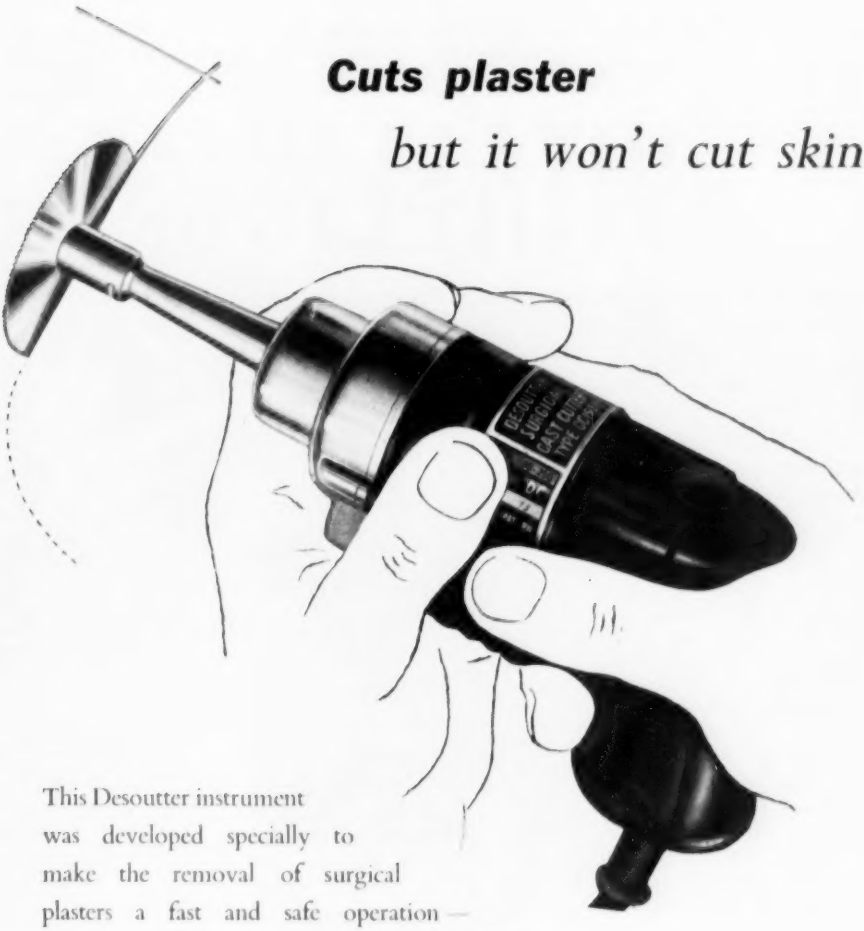

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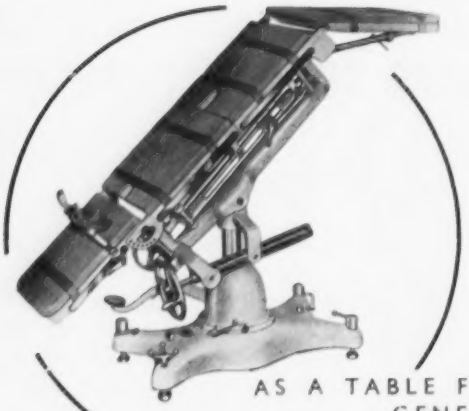

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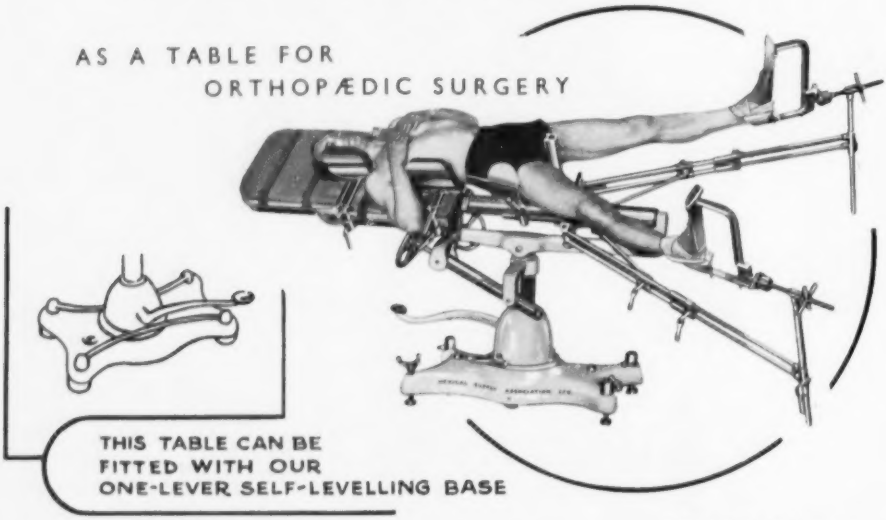

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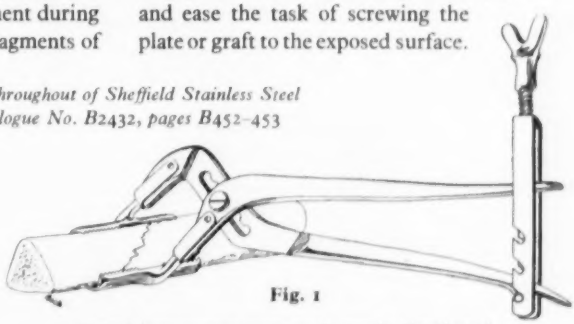

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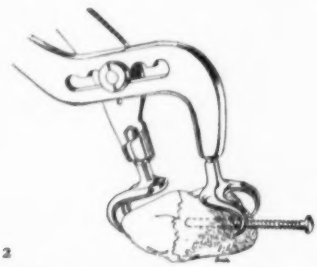
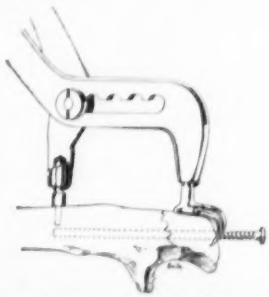


Fig. 2

Hooked jaws used to grip a fractured patella.



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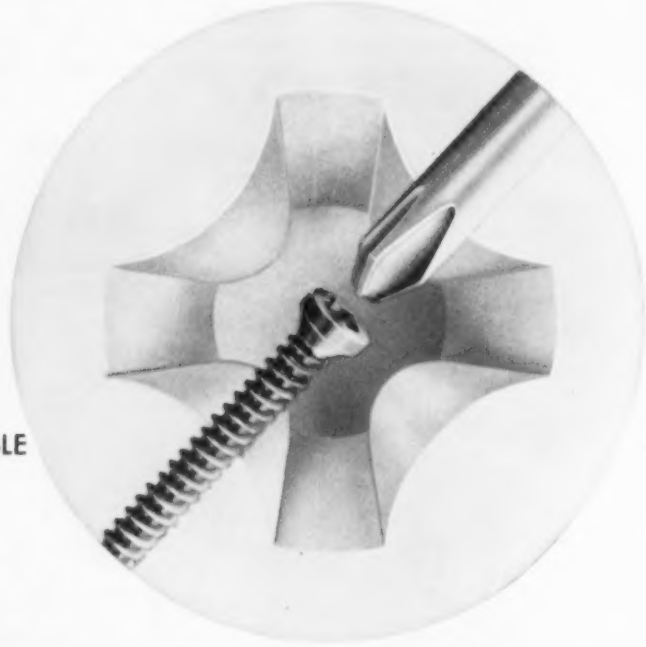

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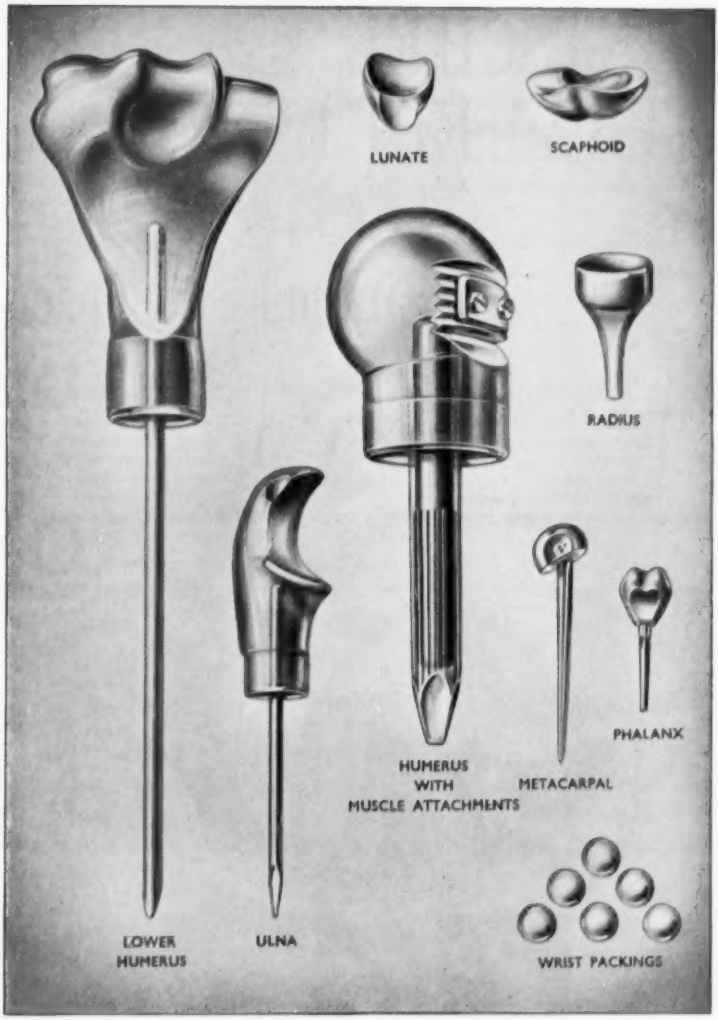

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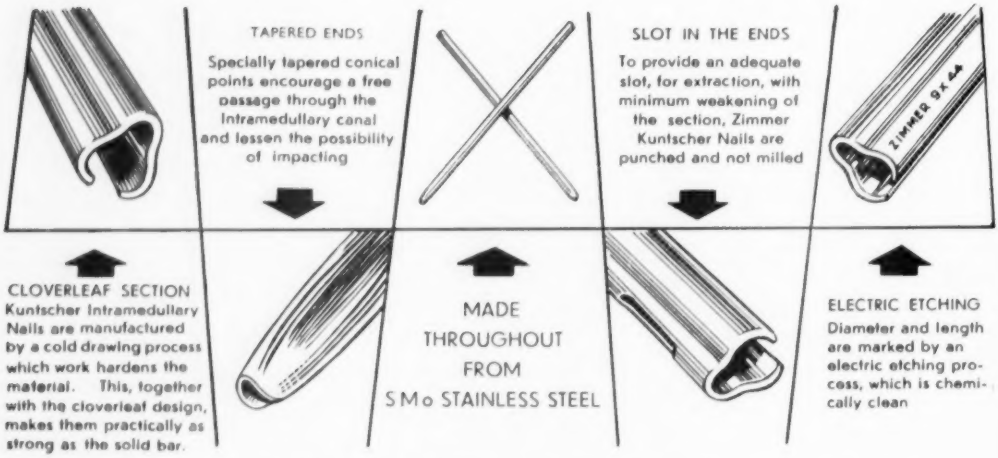
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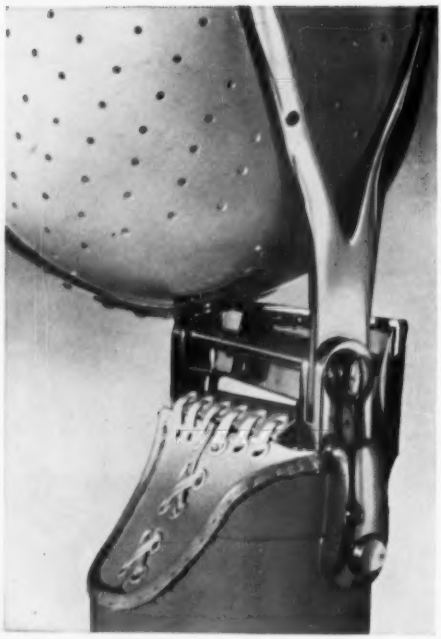

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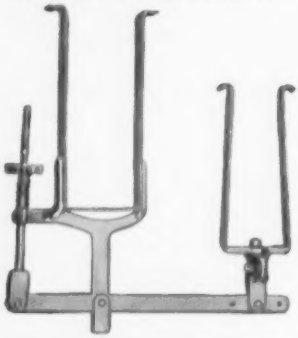

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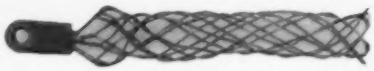

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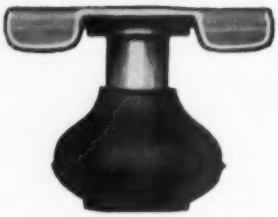

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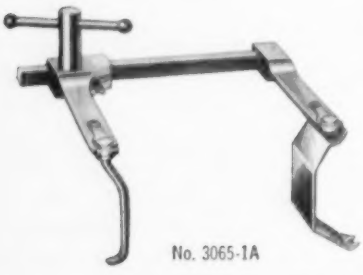

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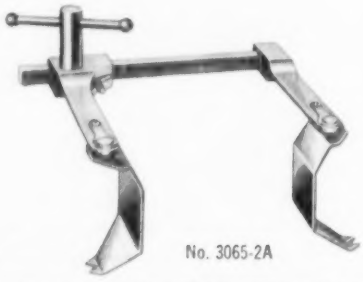

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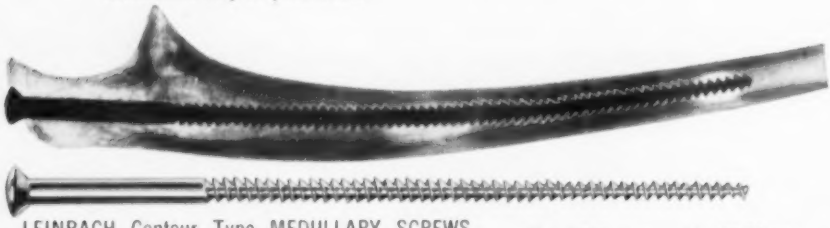

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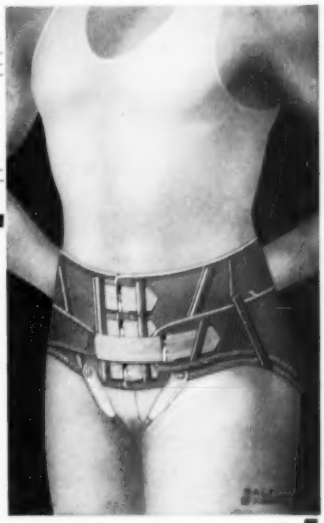

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